This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

LANE MEDICAL LIBRARY STANFORD
2 45 0418 6843

Y DOCUMENT. No. 56.

REPORT

ON

SEWERAGE

IN THE

CITY OF PROVIDENCE,

MADE BY THE WATER COMMISSIONERS AS A COMMITTEE CONSTITUTED BY THE BOARD OF ALDERMEN TO CONSTRUCT CERTAIN SEWERS,

TRANSMITTING A REPORT ON THE SUBJECT MADE TO THEM

BY

J. HERBERT SHEDD,

CHIEF ENGINEER OF THE PROVIDENCE WATER WORKS.

FEBRUARY, 1874.

PROVIDENCE:
HAMMOND, ANGELL & CO., PRINTERS TO THE CITY.
1874.

I585
R4P9
1874

LANE

MEDICAL LIBRARY

LEVI COOPER LANE FUND

1873–74. CITY DOCUMENT. No. 56.

REPORT

ON

SEWERAGE

IN THE

CITY OF PROVIDENCE,

MADE BY THE WATER COMMISSIONERS AS A COMMITTEE CONSTITUTED BY THE BOARD OF ALDERMEN TO CONSTRUCT CERTAIN SEWERS,

TRANSMITTING A REPORT ON THE SUBJECT MADE TO THEM

BY

J. HERBERT SHEDD,

CHIEF ENGINEER OF THE PROVIDENCE WATER WORKS.

FEBRUARY, 1874.

PROVIDENCE:

HAMMOND, ANGELL, & CO., PRINTERS.

1874.

LANE LIBRARY

I585
R4P9
1874

OFFICE OF THE WATER COMMISSIONERS,

PROVIDENCE, February 19, 1874.

To the Honorable the Board of Aldermen: —

The undersigned respectfully transmit a Report made to them by J. Herbert Shedd, Chief Engineer of the Providence Water Works, embracing the information called for by the following Resolution, passed by your Honorable Body, 26th November last: —

"*Resolved*, That inasmuch as the present system of sewerage was adopted by a committee appointed by the board of aldermen, and all the work done by said committee has been carried on in accordance with plans sanctioned by the board; and the action of said committee has, from time to time, been reported to and approved by the board; and inasmuch as the work to be done hereafter will be carried on by the water commissioners, under an ordinance of the city council: therefore the committee aforesaid be, and they are, hereby instructed to report in print to this board such information as they may deem necessary to a proper understanding of the general plan on which such sewers have been constructed, together with their reasons for adopting such plan, and also a comparison with the practice of other cities."

JOSEPH J. COOKE,
CHAS. E. CARPENTER,
WILLIAM CORLISS,
} *Committee.*

3

1645

SEWER REPORT.

PROVIDENCE, R.I., Feb. 12, 1874.

To MESSRS. JOSEPH J. COOKE,
CHARLES E. CARPENTER,
WILLIAM CORLISS,
Committee on Sewers.

GENTLEMEN, — I have received a copy of the following resolution passed by you: —

"*Resolved*, That the resolution passed by the Board of Aldermen, Nov. 26, 1873, asking the Committee for information in regard to the general plan on which sewers have been constructed, etc., is hereby referred to the Chief Engineer, who is requested to report to the Committee the information which it requires."

Enclosed therewith was a copy of the resolution of the Board of Aldermen.

In accordance with these resolutions, I respectfully submit the following

REPORT.

An artificial existence must, to a certain extent, arise wherever masses of human beings congregate. Each individual is influenced by the habits and practices of those around him; and the preservation of the health of every class is equally important to all.

Sanitary laws and regulations are intended to give power to communities, which single individuals cannot possess, to promote measures for securing or improving the state of public health; and the extent to which good sanitary measures are carried indicates, in a degree, the state of civilization and refinement.

The modern works of sewerage and water-supply have been experiments made for improving the health and comfort of communities; and it is evident from public records that they have largely accomplished the end for which they were designed.

Three distinct and important objects are to be accomplished by the proper sewerage of a town: —

1st, The ready conveyance of storm-waters without damage to public or private interests.

2d, The efficient drainage of the subsoil and foundations of buildings.

3d, The quick removal of fecal matter and liquid refuse from dwellings.

The disposal of excreta has caused by far the greatest amount of discussion, and difference of opinion, among those who have given special attention to the subject of sanitary engineering. The question, in a broad sense, resolves itself into this: "What is the cheapest and most efficient technical process for rendering human excreta useful, instead of dangerous?" It is generally conceded, now, that no time should be lost in freeing habitations from the dangerous infection of putrefying substances: and the first object must

be to get rid of the sewage in an unobjectionable manner; and the next to utilize it, if possible.

Many methods have been proposed, and adopted, in their turn, for the removal of such matter, and for securing good sanitary conditions.

Some have advocated the plan of burning all the waste products of populous places.

Others have urged the view that air is the best agent for removing these matters, and that the pneumatic system is the proper one to be adopted.

Others recommend earth as the best medium for the removal of all fecal and decomposing matter from habitations.

By others it is maintained that the water-carriage system is the only feasible plan that can meet the varied requirements of a dense population.

Neither of these schemes is suited to the removal of all the refuse matter from houses and other buildings. The liquid filth, which exceeds in amount all the other, cannot well be taken care of by fire, air, or earth; while water is unsuited to the removal of street-sweepings, ashes, and solid vegetable and animal refuse from houses.

The use of any other than the water-carriage system requires the retention of fecal matter, for a time, on the premises, as it can only be periodically removed. The retention of such matter heretofore, in the absence of proper sewerage, has usually been in cesspools, underground, among the houses, into which all the sewage from the house is discharged. In them the filth accumulates and putrefies, until it is at intervals removed by manual labor. They act like immense brewing-vessels, sending up deadly vapors, which have no escape, except back into the house, among the inhabitants. They also frequently leak; and, if any well is near, the water is poisoned. Fevers and many other diseases, especially among children, are certain to break out, and become malignant, if the emanations from such filth exist in the air around dwellings. Not unfrequently the direct

passage of foul liquid from the cesspool to the well is shown by the mass of blackened and offensive earth lying the whole distance between the two; and it is often found that the cold-air passages for supplying house-furnaces have been made foul by the soakage from cesspools.

It is of the utmost importance to do away with such a state of things; and it is not to be wondered at that many plans have been proposed for that purpose.

Those who have advocated the burning of all refuse have not succeeded in getting their plans adopted to any great extent.

The "*Pneumatic Sewerage System*" has been very strongly urged. The following is given, by the advocates, as a general description of the arrangements: "Small iron reservoirs are placed under the pavement of all principal street-crossings, each reservoir being connected by means of small iron pipes with the privies of the houses next to it, in such a manner that no offensive gases can escape; in other words, from every single privy a continuous air-tight passage leads into the next subterranean street-reservoir, without the intervention of any cesspool.

"The pipes are provided, each one, with a valve, to be worked from the sidewalks of the street, so that the communication between each privy and a street-reservoir can be established or cut off at will. These valves remain always hermetically closed, except during a short moment when the privy contents are to be discharged into the street-reservoir connected with it, which occurs during the night, in the following manner: —

"A locomobile steam-engine, working an air-pump, is driven near the small subterranean street-reservoir, to exhaust the air out of it and out of the entire system of main and branch pipes up to the hermetically-closed house-valves, which are then, one after the other, opened and shut again, thus discharging the privy contents, including all gases, into the street-reservoir.

"If the vacuum made in the reservoir and pipe-system is

complete, or nearly so, the mechanical force of the atmospheric column rushing in the moment a house-valve is opened equals that of some thirty hurricanes. In order to maintain this vacuum while a number of privy-pipes are discharged, one after the other, the air-pump standing near the reservoir is kept continually in motion, creating a constant draft, which causes all discharges to fly just into the reservoir, and nowhere else, like so many shots from air-guns.

"The urine, exceeding the solid fæces about eight or nine times in volume, affords sufficient moisture, not only to prevent the excrements from drying or caking, but also to keep the whole mass in so fluid a state, that removal is easy, unfailing, and complete, especially under the above-mentioned powerful blast operating upon it. All the privies and their pipes will thus be every day thoroughly cleaned of solids, fluids, and gases, and be filled with fresh air instead.

"After all the house-valves have thus been successively opened and shut, an operation which practice has shown can hardly be done quick enough, the small reservoir itself is emptied by pneumatic pressure into an hermetically-closed waggon-reservoir attached as a sort of tender to the air-pump carriage. This done, the connecting hoses, by which the movable apparatus communicates with the stationary one under the pavement, are uncoupled, and the locomobile with its tender proceeds to the next reservoir, and then to another and another, until the tender is filled.

"As the particular street-reservoir where this will occur can by practice be pretty accurately known beforehand, arrangements are made, that, when arriving there, the locomobile meets an empty tender drawn by two horses, which changes place with the full one; thus allowing the sewerage operation to go on without interruption, the filled tenders being always drawn away by the horses to a temporary dépôt, where they are decanted by direct hydraulic pressure into air- and water- tight barrels, which are then at once sent like any other goods, by rail or steamboat, to the lands requiring the excellent fertilizer thus collected."

All this requires very expensive structures of iron, connecting with every house, and a degree of perfection in the operation, which, for any great length of time, would probably prove impracticable.

This plan is comparatively new and untried; while it deals with but a small part of the refuse that must be removed. The scheme is certainly not in a condition to warrant its introduction in this community at the present time.

The treatment of excreta by dry earth has found many advocates. It is stated that this system "is founded on the fact of the deodorizing power of earth; a *given quantity* of *dry* earth destroying all smell, and entirely preventing noxious vapors and other discomforts. The practical application of this power consists in a reservoir for containing *dry earth*, and in an apparatus for measuring and delivering the requisite quantity, so as to deal with every operation in *detail*." The plan has been successfully used in barracks, hospitals, prisons, and schools; but there are strong objections to its adoption for a large population. The earth *must be dry*, pulverized, and immediately applied. No water can be used, and "any incidental drippings of fluids must be covered and absorbed by dry earth." The earth "should be a clayey loam, friable, and thoroughly dried. No soil must be used which contains vegetable matter." Sand is in no way suitable. "Dr. Ross estimates the total quantity of earth required to deodorize the whole excreta of an adult at 9¾ lbs." per day. A cubic foot of dry earth would therefore supply about ten persons one day. If we assume the population of Providence to be equal to sixty thousand adults, there would need to be supplied to the whole city six thousand cubic feet of dry earth each day. At the ordinary depth of soil in this vicinity, I think, a quarter of an acre of land would need to be stripped every day in the year to supply the demand, or ninety acres each year. As there are many rainy days, and much time when the ground is frozen, the difficulties of this operation would be considerable. After having been procured in suitable condition, this earth must be transported to

the city, and its equivalent, with the added impurities, taken away each day.

Some difficulty has been found in keeping the self-acting apparatus in order; and the opinion has been expressed, that, in large towns, their use is "highly dangerous to health."

After all the trouble, expense, and danger attendant upon this scheme, it deals only with a small part of the refuse that must be removed from dwellings. It has been found, that, "for every pound of human excreta removed under the dry-earth system, there are in every well-regulated establishment about 190 of fluid refuse, which must be otherwise disposed of." Some provision must be made to convey away this fluid refuse; and, when proper drains are made for that purpose, the extra expense of including the fecal matter will be very small.

During the first two or three days after sewage is deposited in water, the smell is unpleasant, but not dangerous to mankind: after that, putrefaction begins, and the gases given off become deleterious. This interval gives ample time for removal by water-carriage under a good system; and, if it is not improved, punishment by disease will surely follow.

Many persons object to such a disposal of this matter on the ground that a valuable manure is thus wasted; but the efforts to save it have heretofore, except under peculiarly favorable circumstances, proved very unprofitable, as well as inconvenient, and often dangerous.

Perhaps the most extensive scheme for saving fecal matter by means of cesspools is that adopted by the French Government, and put in practice in several large cities and places in France. The drains accommodate, as sewage, only rainfall and household water, except the contents of a comparatively small number of public urinals. Night-soil is received into cesspools, and in all cases is carted away from the city, and deposited in appointed places. A certain proportion — as much as finds a ready sale — goes to deodorizing works, and is converted into manure; but large quantities are still wasted.

Mr. Robert Rawlinson, an eminent sanitary engineer, holding several important commissions in the British Government in that capacity, said, in a discussion before the Institution of Civil Engineers in London in 1865, "With regard to the Parisian sewers, it had been stated that those sewers were made to take away surface-water only, and not sewage. He was sorry to say that that principle had been adopted by the French Government in other cities and places: in Lyons and Marseilles, for instance, the same system was carried out. Large sewers were constructed, with subways for the passage of carts and railway trucks, which received the refuse emptied out by hand-labor: that refuse, if the sewers had been constructed upon proper principles, would have been carried out by the action of water flowing regularly through them." "The Parisians committed the fatal mistake, about the year 1820, of insisting, by ordinance, on cesspool construction. It was recorded that the whole subsoil of Paris was on the point of becoming putrid with cesspit matter, and that the ordinance was passed in consequence. By it all cesspits, as matters of private construction, were abolished; and the construction of cesspools upon a gigantic scale was undertaken, or dictated, by the municipality; and all persons thereafter building hotels or houses were obliged to construct 'hermetically-sealed cesspools' after a municipal or royal pattern, which had been devised by the government engineers of France. Into these cesspools, effete matter from water-closets, grease and washings from the sinks, and other such refuse, was to be discharged. He considered Paris, when he visited it twelve or fourteen years ago, to be, on the surface, perhaps, the cleanest city in the world. Nothing could be more beautiful than the order and cleanliness of its paved streets; but the stench, even in the best houses, was almost insupportable. The possibility of hermetically-sealed cesspools was, therefore, a fallacy."

While the climate of Paris is more favorable to health than that of London, the rate of mortality is higher; indi-

cating that the sanitary works of London are more effectual and perfect than those of Paris.

It does not follow that the water conveyed by sewers, from which fecal matter is excluded, is, therefore, any less impure than the contents of sewers receiving all kinds of refuse. Experience in this country and in Europe has proved that no appreciable difference exists in the offensiveness of sediment taken from sewers which do not, and sewers which do, convey matter from water-closets. Corfield says, "Any one who has examined the sewers of Paris, Lyons, or any other town where the cesspool system is as efficiently and thoroughly carried out as it can be, knows perfectly well that the sewage is just as foul, just as offensive in every way, as it is in the most thoroughly water-closeted town."

The most promising plan for utilizing the manurial properties of city sewage, at the present time, is by surface irrigation; the ordinary flow from the sewers being pumped through pipes to distant fields, and there made to flow over grass lands prepared to receive it.

For the entire success of this plan the climate must be so mild that grass will grow nearly all the year, and a large area of porous soil, not likely to be needed for other than agricultural purposes, must be available within reasonable distance. Garden vegetation is sometimes treated by sewage irrigation.

An object which has thus far been more important than the saving of fertilizing products is in large measure accomplished by this plan; that is, avoiding the pollution of rivers.

It is probable, that for inland towns, and possibly for populous places on small salt-water basins, there will be, before many years, an imperative popular demand for the purification of sewage before its discharge into rivers or harbors. Artificial filtration through earth has been practised for this purpose; and it may be that irrigation for farming-purposes during the season when that is practicable, and filtration during the winter season, can be so combined

as to relieve the water-courses, even in our northern climate. Perhaps some one of the "Precipitation Processes" may prove valuable in this connection.

At present, the amount of impurity from our sewers is so small, when compared with the volume of water in the harbor into which it is discharged, that no great inconvenience will be felt, except where the outlets are at unfavorable points.

The Annual Report of the State Board of Health of Massachusetts for the year 1873 contains a report from Prof. William R. Nichols and Dr. George Derby, in which they conclude, from numerous analyses of the sewage of Boston, that its average value is about one cent per ton; and, from numerous analyses of the sewage of Worcester, they conclude the average value of the dry-weather sewage to be about seven-eighths of a cent per ton.

This whole subject has received, and is now receiving, the earnest and careful attention of many very able minds; and expensive experiments are being carried on upon a large scale in many places. In fact, "nearly the whole civilized world is not only interested in this problem, but directly or indirectly engaged in seeking its solution."* The results, however, are not yet sufficiently defined, I think, to warrant any decided conclusions; and while the sanitary engineer will feel bound to recommend that sewerage works be so constructed, where practicable, that they may eventually form part of a plan for the utilization of the waste products, or avoiding contamination, without great expense in changes, he is hardly warranted in actually executing work, at present, to do more than fulfil the first requirement of a system for the removal of refuse; which is, to get rid of the sewage quickly, in an unobjectionable manner.

This can be most effectually and safely done by the water-carriage system, which provides for the removal of the greater portion of all refuse, and is capable of being combined in one system with the conveyance of storm-waters, and the drainage of the subsoil, and foundations of buildings.

* E. S. Chesbrough.

Sometimes these objects are accomplished by separate and distinct systems of pipes, or sewers, in the same streets; but the experience of cities seems to be unfavorable to this plan, and the practice is largely in favor of combining all in one system.

Such a combined system is partially devised, and to some extent executed, in the city of Providence.

Mr. E. S. Chesbrough of Chicago, who has deservedly the highest reputation in this department of engineering, has given the following as the

REQUISITES OF GOOD DRAINAGE.

"To drain a city perfectly, the sewers should be of such size, form, inclination, workmanship, and depth below the surface, as to convey, without deposit or stoppage, to the main outlet, and by means of the ordinary quantity of water used for domestic and other purposes, all the substances that are usually discharged into them from private houses, street-surfaces, and, when not injurious to the health of the men who have occasionally to enter, examine, cleanse, or repair them, all the liquid refuse from manufacturing and other establishments. These requisites are not always attainable at a reasonable expense; and hence compromises are often resorted to, especially when it is deemed impracticable to raise the funds necessary to carry out a perfect system. For this reason, sewers are often laid too shallow to drain thoroughly the soil beneath the foundations of buildings, and with inclinations too slight to prevent deposits from forming in them."

The proper position for the "main outlet" must be first considered when a scheme for sewerage is being planned.

"If the sewage is discharged into any stream or body of water too small, or shallow, or sluggish, to deodorize and

neutralize it with sufficient rapidity, it will, sooner or later, become a nuisance that must be abated at whatever cost.

"To avoid or remedy this nuisance, vast sums have already been expended in the construction of intercepting sewers, pumping, irrigating, and deodorizing, and other works, in Great Britain and on the continent of Europe; and the cities of this country are already seriously considering the subject."

"With all the light at present possessed on this subject, there appears to be no other feasible method of disposing of the sewage of cities, especially in the northern and colder portions of our country, than that of conveying it to some comparatively rapid stream or body of water agitated by winds and waves, and sufficiently extensive to neutralize it. In this connection, a practical question of great importance often arises with regard to what is sufficient to neutralize sewage, or render it innocuous. It will be evident, upon the least reflection, that several elements must be considered. The population of two cities may be equal; but the habits and industries of the two, and consequently the quantity of sewage from them, may be very unequal.

"If the quantity should be the same, the character may be very different in some respects. Fresh and salt water are very different in their capacities for neutralizing sewage, the former being decidedly superior in this respect.

"While small towns and cities often experience little or no inconvenience in disposing of their sewage at first, they become more and more embarrassed with it as they increase in size. The most that has been done hitherto in this direction has been partial and experimental; but the experience of the past is of great value in the planning of new works.

"The results of the grand systems of intercepting sewers, carried out in London and Paris, show clearly that it is possible to relieve, to a great extent, the inhabitants of large cities of the evils of discharging their sewage into receptacles from which it is sent back to them through the air. And yet the outlets of those intercepting sewers are com-

plained of; showing that the nuisance, while removed from the many, is imposed upon a few. For this reason, various schemes have been proposed, and some experiments made, to remedy the evil altogether; but thus far only a small portion of the sewage of either city has been disposed of except by discharging it low down into the Thames or the Seine." *

The main outlets in the city of Providence have been arranged, so far as seems practicable, to discharge the sewage into the river or harbor as much below the drained district as possible. It is supposed that eventually one or more main intercepting sewers will be required on each side of the city to collect these outlets, and discharge their flow at points still less objectionable. The present locations of the outlets of the new sewers are reasonably satisfactory, except in the case of the Dorrance-street sewer, which empties at the head of the dock. Some provision ought soon to be made, either to extend this sewer to the end of the pier, of its present size, or to lay a smaller outlet, which might be of cast-iron pipe, to take the sediment and ordinary liquid filth into deep water, while the storm-waters continue to discharge at the present outlet.

DRAINAGE DISTRICTS.

The total area of land within the corporate limits is about 6,014 acres, as taken by scale from the city maps, or about nine and four-tenths square miles.

The Woonasquatucket River and the Providence River separate this area into two natural divisions, known as the "East Side" and "West Side." The Moshassuck River cuts off a portion of the East Side, making a small division, which includes "Smith's Hill."

The drainage of each of these natural divisions has been considered separately, except that a portion of North Provi-

* Report of E. S. Chesbrough to the City of New Haven, Dec. 30, 1872.

dence, near Olneyville, has been taken into consideration in planning the drainage of a portion of the West Side.

Subdivisions, or "drainage districts," are naturally made in the larger divisions by the contour of the ground; and the drainage for each of these districts may be considered separately, except that the outlets or main drains must be planned in connection with those of other districts which have the same final discharge.

Not all the districts, however, are such as would be formed naturally by the contour of the ground. In some cases, intercepting drains have been planned to divert the drainage into new channels.

Where a drainage district lies partly within, and partly without, the city limits, the whole area is, of course, considered.

The general extent and location of the districts, which, for convenience, have been designated by letters of the alphabet, may be seen by reference to the map which accompanies this Report. The limits represented are liable to change in some places, after more complete and accurate information has been obtained. For a portion of the territory, the drainage districts have not been sufficiently defined to warrant representation.

It is regarded as of sufficient importance, at the present time, to construct the sewers, where practicable, so as to keep the ordinary sewage flow out of the Woonasquatucket River and the Cove Basin. This requires a portion of the sewage of district P to be carried a long distance, as will be noticed by inspection of that district on the map.

It is not proposed to construct the main sewers of this district large enough to take all the water from the greatest storms, but to provide, at intervals in the line, for the overflow of storm-waters into the Woonasquatucket River or into the Cove Basin. When the rainfall is of small amount, it is generally loaded with impurities; but the later run of a heavy rainfall is comparatively pure. With the main sewers large enough to take all the rainfall of ordinary storms, —

the limit of quantity to be carefully determined, — and, of course, capable of taking, to the same extent, the first run of water from the heavier storms, the excess of that which comes later may safely be allowed to overflow into the natural channels. This can be accomplished by weirs properly placed, and discharging into drains which lead to the natural water-courses.

The greater portion of the rainfall on district Q, if it should run on the natural surface or on the established grades of the streets, would flow into district P, where the grades of the main sewers must be so flat, that a much larger size of drain would be required to carry the same amount of water than would be required on such grades as can be obtained on an intercepting sewer in district Q.

The objection to large sewers in district P is not simply that they would be more expensive in themselves, but the land all along the Woonasquatucket River would need to be filled higher than will be necessary with smaller sewers.

The height of the outlet, which is through Dorrance Street, is fixed by low tide in the harbor; and the grade of the main sewer will be one in a thousand, which is about five feet in a mile, and is regarded as the lowest allowable in that place. The tide will ebb and flow in the sewer for about a mile of its length.

Probably it will be best to make connection between the Woonasquatucket River and this main sewer at some point near the junction of High Street and Broadway, for the purpose of flushing the sewer with river-water when necessary.

A large portion of the territory enclosed by Providence River, Ship Street, Eddy Street, Cove Street, and Exchange Place, about forty-eight acres in extent, on which, probably, the most expensive buildings in the city stand, is only from 3½ to 7 feet above mean high tide. When the sewerage system is complete, and the waters of a rainfall are gathered quickly, and carried rapidly to the outlet, there will be trouble enough with the drainage of this low district, if we keep out of it all the water that it is practicable to turn in some other course.

With this object in view, an intercepting sewer has been constructed from Atwell's Avenue, through Bourn, Jackson, High, Chestnut, and Elm Streets, to Providence River. This diverts the drainage of about two hundred and seventy-four acres, which would otherwise flow into the low district above defined.

I recommend that a similar intercepting drain be planned, to take the drainage from district Q, through a new street to be laid out from the junction of Ridge Street with Atwell's Avenue, to Acorn Street, where the extension of West Exchange Street would intersect that street, and thence to West Exchange Street as now laid out. The attention of the Board of Aldermen has been called to the need for this street, and the ground has been examined by their committee on streets. The drainage of an area of about one hundred and ten acres, extending from the Dexter training-ground to the new street, would be diverted by this drain. The proposed location for the street is indicated on the map by dotted lines.

The construction of these intercepting drains will probably be favorable to any future scheme for the utilization of the sewage.

They furnish also an element of safety, as the volume of rainfall is brought more under control than would be the case if it was allowed to flow into the lower districts.

The drainage of the Ninth Ward is a difficult problem. Much study has been given to it; but the conclusions are not yet very definite, except as to the lines desirable for the trunk sewers. As these lines are generally through private property, the attention of the Board of Aldermen has been called to the matter, with the suggestion that streets be laid out to accommodate the sewers on portions of the main lines. Further action by the Board is desirable before the plans are proceeded with. The three principal lines of drainage judged to be desirable are as follows: First, from Public Street, between Broad Street and Prairie Avenue, to the junction of Colwell Street with Prairie Avenue; thence on Colwell Street to a point in line with Ocean Street con-

tinued; thence through the junction of Plain Street with the Old Stonington Railroad location, across Eddy Street, and along Old Maid's Cove to Sassafras Point. Second, from Public Street, between Mashapaug Street and Austin Street, running southerly, parallel to Hamilton Street, to a point in line with the continuation of Gallatin Street; thence, in said continuation, westerly about five hundred and fifty feet; thence southerly, parallel to Hamilton Street, to Roger Williams Avenue; thence easterly, in said avenue, to the Old Stonington Railroad location; thence north-easterly, in or near said location, to the first-named main line of drainage at Plain Street. Third, from Maiden Lane, near the location of the New-York, Boston, and Providence Railroad, running south-easterly, in or near said location, to a point in line with Bartlett Street continued; thence in said line of Bartlett Street to the second-named line of main drainage.

The proposed locations of these lines are indicated on the accompanying map.

A much less expensive main sewer could be constructed from Roger Williams Avenue to the outlet at Sassafras Point, if it were allowable to turn the excessive storm-waters through the brook into Cunliff's Pond; but I am advised by the City Solicitor, that, in his opinion, this would give rise to expensive litigation and damages, and that the cost of taking all the waters on to the outlet had better be incurred.

SIZE OF SEWERS.

The practice of apportioning the size of sewers to the work they have to do, seems, as a general rule, to be comparatively recent. The only rule appears to have been to make a difference between the sizes of mains and those of laterals, and to get them all large enough.

The first sewers were probably streams, or natural brooks, running through the town, and covered over to fit them to take the overflow from the cesspools, as well as the rain-water from the streets.

The famous Cloaca Maxima of Rome was employed to carry fecal matter as well as storm-waters; while, on the other hand, it was in England, until within sixty years, a penal offence to turn cesspool matter into the public sewers. And the first act making it compulsory to drain houses into sewers was passed in 1847.

When the covered brooks failed to give sufficient drainage, and became foul from deposits, large sewers were planned for the surface-water and sewage; and, with the idea of the bed of a natural stream in view, it was thought necessary to make all the main drains large enough for a man to pass through them, and keep them clean. "Vast numbers of these great main sewers still exist. Into these sewers all the smaller house-drains were to enter, and the surface-water through the street-gratings as well. The ordinary water used for domestic purposes, and the occasional rainfalls, were relied upon to flush those large main sewers; but their great size made this an exceedingly difficult and uncertain process, and they, in fact, became only cesspools elongated. In dry weather, the filth was retained in them to such an extent, that, after heavy rains, chemical analysis showed that the water which was discharged contained frequently twenty times the amount of human fecal matter per gallon more than it did in dry weather. This state of matters, added to the fact that long-continued dry weather was always attended by an increase of deaths from typhus and other fevers, clearly showed that something more must be done. A further step was then taken by sanitary engineers. The idea of men passing up the drains was set aside, and the smallest possible drains were constructed, until these have arrived at such dimensions as an 18-inch main drain for a town of 10,000 inhabitants. The rainfall was still to be relied on to a certain extent for flushing purposes; but a supplementary assistance was to be given at some points by flushing with water from the ordinary regular supply of the town."

In order to be "self-cleansing," sewers must be adapted, in their size and grade, to the amount of sewage they have to

carry. If the ordinary run of water is spread thin over a broad surface, the scouring effect is lost, and deposits will occur; but with the same amount of water gathered in a narrow channel, and running deep, — the best sectional form being semicircular, — the scouring effect is greatly increased, and the sewers are likely to keep themselves clean.

An experiment in Upper George Street, in London, was made in the main line of sewer, which is 5 feet 6 inches high by 3 feet 6 inches wide, by laying a 12-inch pipe on the invert, and building a head-wall at the end of it, so that the whole of the sewage discharged by the collateral sewers was forced to pass through the pipe.

"The velocity of the stream in the pipe has been observed to be four and a half times greater than the velocity of the same amount of water on the bed of the old sewer." "The superficial velocity of the water in the pipe is generally three, four, and five times greater than the superficial velocity which obtained under the same circumstances in the original sewer; and the velocity of the whole mass of water in the pipe approximates much more to its surface velocity, as ascertained by a float, than does the velocity of the whole mass of water in the sewer approximate to its own surface velocity."

The recognition of this principle of the increase of velocity by the concentration of the sectional area of the flow was largely influential in causing many engineers to abandon the idea of cleansing sewers by sending men into them to do it by hand. They relied mainly on flushing the sewers by dashes of water in great volume, aided by some means of stirring up the deposit previous to and during the rush of water.

Perhaps it was natural for men who had set up a new system, which they felt called upon to defend against the attacks — often hot and persistent — of those who adhered to the old system, to push their theories to an extreme, and adopt plans almost as bad in an opposite direction as those they sought to supersede. The "Pipe-and-Brick-Sewers war" had, I think, the effect to cause such results in a few cases; but the middle course is now very generally adopted,

and sewers are more nearly suited to the work required of them. The result is a great decrease in first cost, and a still greater decrease in the proportionate cost of maintenance.

Some of the old sewers of Europe are of enormous size; and at the present time it is not uncommon in Paris to take visitors on excursions through the principal sewers in boats. The sewers bear the same names as the streets above them; and the house-connections are numbered. Foot-paths and rails for carrying-wagons are used, and water-pipes and gas-pipes are enclosed in the drains. The old sewers were not so large as the new; but "the smallest section ever built, under either the old or the modern system, was 5 feet 6 inches high by 2 feet 3 inches wide at the springing of the roof." It will be remembered that these sewers are for surface-water only. The cost of cleansing these sewers is very great.

From a paper on the Drainage of Paris, read before the Institution of Civil Engineers in London in March, 1865, it appears that the cost of cleaning amounts to about £30,000, or about $145,000, a year, on a length of 217 miles, including the pay of twenty-three officers and four hundred workmen. At that rate, the cost of cleaning the sewers of London would have been about $870,000 per year. In the discussion upon the paper, Mr. W. Haywood said of the sewers in Paris, "He had ascertained that about three men were required to every two miles of sewers, these men being entirely engaged in helping to keep that length of sewer clean; and the total cost for wages, superintendence, lighting, clothes, &c., he believed, was about £100 per mile per annum: while in London the whole cost of cleansing the sewers, including the expense of water for flushing and the labor bestowed upon their interior, and also of keeping the gullies and ventilating-shafts in condition, — which in the city, owing to the enormous traffic, was a work of considerable labor, and a heavy item of expense, — was about £40 per mile per annum. But, though the sewers in the city were kept clean, they were undoubtedly not in such a state in that respect as the sewers of Paris."

The 1,300 miles of old sewers in London were certainly not models for a system of self-cleansing sewers. Mr. Robert Rawlinson said of them in the same discussion, "Many miles were in ruins, and choked with filth to such an extent, that no ordinary application of water could remove it; and which, at great labor and expense, had now to be removed by shovels." But the size and shape are so much nearer what is required for the ordinary flow of sewage, as to keep the cost of cleansing, even under such serious disadvantages, at two-fifths the cost of cleansing the sewers of Paris, which are understood to be in excellent condition.

The Croton Aqueduct Board use the following language in their Report, dated Jan. 3, 1870: "The system of sewerage which has been adopted by this Board was recommended by the former chief engineer, Mr. Craven (after an experience of nearly twenty years as chief engineer of this department), and was determined on only after a careful study by him of the systems advocated and adopted in Europe, and especially in London, where the subject of thorough and economical drainage had been extensively discussed and experimented on. It has worked well where it originated; and has, as far as we have experience, without exception, worked well here.

"The Board are perfecting and extending the new system as fast as a just economy will allow, and correcting the old arrangement of sewers, which were built without their control, and without any harmonious plan.

"The cost of brick sewers, as built under the old plan, would be about three times that of the pipe sewers, which are their efficient substitute.

"In the matter of cleaning and repairs, the discrepancy is still greater.

"There are now upward of 60 miles of the pipe sewers in operation in this city. Instances of failure have been extremely rare; and in all cases they could be traced directly to unfaithful construction on the part of contractors, — a contingency from which no works are exempt.

"The cost of repairing all of these defects in 60 miles of this sewerage has not exceeded $3,000; and for cleaning, and removing obstructions, for the past year, the cost has not exceeded $500.

"There are 261 miles of brick sewers in the city, for which the cost of cleaning, and removing deposit, for the past year, has been $27,730; showing that, while the extent of the brick sewers is only 4⅛ times that of the pipe sewers, the cost of cleaning has been more than fifty times greater."

The size of the pipe sewers is indicated in the Report for 1865, where it is shown that about five-sixths of the sewers planned for eight drainage districts "will be vitrified stone-ware drain-pipes of from 12 to 18 inches internal diameter." I have the dimensions of only two of the outlet sewers of the system adopted by the Croton Board: that of sewer district No. 3 was 10 feet wide and 5⅔ feet high in the clear; and the outlet of district No. 5 was 8 feet wide and 5½ feet high in the clear.

From the Report of the Chief Engineer of City Works of Brooklyn, dated Jan. 1, 1873, I find that the total length of sewers laid in that city is about 232 miles, of which about 188 miles are pipe sewers, and about 44 miles are brick sewers. About 120 miles are only 1 foot in diameter; and about 78 miles are from 15 inches to 24 inches in diameter inclusive. The largest size — of very short length — is 10 feet in diameter.

I do not clearly understand the tables in regard to the cost of cleansing. Apparently the whole expenditure for "cleaning and repairing" is $26,746.70. I suppose this to include cleaning catch-basins as well as sewers, and repairs upon the sewers and appurtenances; also expense of inspection of house connections other than salaries.

From the Report of the Chief Engineer of the Board of Public Works of the City of Chicago, dated May 30, 1873, I find that the total length of sewers built previous to April 1, 1873, is about 170 miles, of which about 53½ miles are 1 foot in diameter, a small amount is 15 inches in diameter,

and about 55⅓ miles are 2 feet in diameter. The largest sewers are 6 feet in diameter.

The cost of cleansing the sewers for the year ending April 1, 1873, was $13,606.80: the length requiring to be cleaned was about 48⅔ miles. The average cost of cleaning by flushing was $2.25 per 100 feet, and by chain machine $12.54 per 100 feet. The grades, upon the whole, are nearer level than in any other city in this country with which I am acquainted.

The city of Chicago was the first in the United States to use pipe sewers on a large scale. Mr. Chesbrough, Chief Engineer to the Sewerage Commissioners, visited Europe in 1856–57, and made careful and extended observations of the systems in operation there, which confirmed his conclusion that the plan to use pipe sewers was advisable. He says in his Report, dated April 1, 1861, —

"At the time our sewerage plan was adopted, a warm controversy was going on in England between the advocates and opponents of pipe sewers. They had never been used to any extent in the United States. It was difficult to know what to decide upon, as the accounts from England, not only with regard to opinions, but actual results, were so conflicting. It seemed evident to us, that if properly constructed, and not applied to drainage areas too large for them, they might be safely adopted. The experience of nearly five years confirms this opinion, and shows that they not only cost less money than large brick sewers would have done in the first construction, but are likely to cost materially less in maintenance."

Pipe sewers are now in general use through the country.

WHAT DETERMINES SIZE.

The capacity of sewers to carry water depends mainly on their sectional area — if of proper form — and the rate of fall.

In order to render sewers as nearly self-cleansing as possible, they must, as before stated, be adapted, in size and inclination, to the ordinary flow of sewage, so far as to keep

up a velocity sufficient to carry on all light matters, and to leave only so much heavy matter as will be finally carried along by the scouring effect of the storm-waters.

But the ordinary flow is a very small part of what must be taken care of in time of storm. The sewers which have been recently constructed in this city are designed to carry about sixty times as much water as the average ordinary flow of sewage would amount to from a population of 32,000 persons per square mile; and, in providing a sufficient capacity to take this amount of storm-water, the channel for ordinary flow is necessarily such as to cause more frictional surface, in comparison with the volume, than is desirable, especially on sewers of small inclination. This disadvantage is not so great, however, in the modern egg-shaped sewers as in other forms.

There is room for question as to how far the sewers should be made capable of carrying extraordinary storms. The original cost of large sewers, as well as the cost of maintenance, is so much greater, that a city can afford to pay for damages done by storms of unfrequent occurrence, rather than to construct them. Just where to stop in providing for such storms is a matter of doubt; and what would secure true economy in one place would not necessarily do so in another. The frequency of the heavy storms, the amount of rainfall, and the damage likely to be done, depend upon the location and the circumstances of each place.

In the Report of the Engineer to the Commissioners of Sewerage of the City of Brooklyn, on the General Drainage of the City, made in 1859, the following language is used: —

"With reference to the amount of rainfall to be provided for, no system of sewerage yet proposed in any city contemplates the removal of *excessive* storm-waters by means of the sewers alone, — such storms, for instance, as discharge for short intervals two or three inches of rain in the hour. They occur at long intervals, and are of short duration, and the damage is usually confined to limited areas; whilst the construction of sewers to meet the contingency would be

attended with an enormous expense over the whole city both in construction and repair, and of doubtful efficiency when suddenly called upon, and extremely objectionable as conduits for the ordinary flow of sewage."

The conclusion arrived at in Brooklyn was to provide for a storm of one inch in depth per hour, but to assume that not more than half this quantity would reach the sewers during the time of falling, owing to various losses, and to the time required for the water to flow over the surface before reaching the sewer. Col. J. W. Adams was the engineer who determined the plan of sewerage, and who made the report above referred to. When a full description of the works was made in 1865 by Mr. James P. Kirkwood, engineer, he gave a formula to express the practice, which gives sizes slightly smaller than the sizes employed in this city for similar areas and inclinations.

It appears from Col. Adams's Report to the Commissioners of City Works of Brooklyn, dated Jan. 1, 1873, that, during the excessive rain-storms of the previous summer, much complaint was made of surcharged sewers in some localities. Though a considerable portion of this was due to imperfect work on the private drains, and to peculiar circumstances, yet it was in large measure owing to the size of the sewers having been proportioned to a discharge of one inch of rain in an hour. To meet these excessive storms, three shallow storm-sewers were proposed, at a total expense of $50,000, to give such relief as was needed.

It is common, and according to the best practice, in this country and in England, to provide for a rainfall of one inch in an hour.

To ascertain the frequency of such storms, I have had a careful examination made of records kindly loaned to me by President Alexis Caswell, D.D., LL.D., who has kept a very full meteorological register, since 1831 to the present time, in this city.

I give on the following pages a portion of the information obtained in this way, selected and arranged to illustrate this subject.

The following table gives the number of storms in each month of each year, classified according to the amount of rain, so that storms yielding an amount nearest to any given tenth of an inch in depth are collected together. The number of storms is given opposite the month, and under the respective depths.

1832.

	DEPTHS IN TENTHS OF AN INCH.																		Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January	2	1			1	1				1					1						
February	1		2	3			1	1		1											
March	1		2	1			1								1						
April	2	1				2												1			
May		2			2	1															23
June	2	1																			
July	2	1				1			1												
August	3	1		1		1		1							1						
September	1			2				2			1										
October				1		1				1											
November	1					1						1				1					
December	1	1	1	1			1											1			21
Total number	16	8	5	9	3	8	3	4	1	3	1	1			3	1		2			2

1833.

January	1						1			1											
February					1						1										
March	1	2	1	1				1													
April		1			1																26
May	2			2	1	1															
June	2	2			1			1													24
July	1			1			1														
August		2		2						1											
September	2	1	1	1		1															
October	1		1						1	1		1	2								
November			1	1					1				1			1					
December	1	1			1	1	1	1											1		
Total number	11	9	4	8	5	3	3	3	2	3	1	1	3			1			1		2

1834.

January	2	2	1				1														
February		1			2																
March	1		3	1																	
April		2		1	2		1	1													
May	1						1	1							1						26
June	2	1			2	1							1						1		
July						1															70
August			1	1	1																
September	1	1		1		1		1											1		
October		2											2			1					
November	3		1																		29
December	2		1							1					1						
Total number	12	9	7	4	7	3	2	4		1			3		2	1			2		3

1835.

	DEPTHS IN TENTHS OF AN INCH.																			Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January			5			2				1											
February	1		1						1												
March			2		1	1		1			1	1									
April	1	1	2		1			1	1			1									
May	1	1				1		1													
June	2	2		1	2																
July		2	1			1										1					
August	1	2		1											1						
September	1		1		1																
October			1			1															24
November	2	1				1	1														
December													1			1					
Total number	9	9	13	2	5	7	1	3	2	1	1	2	1		1	2					1

1836.

January			1	1	1	2		1													25
February	2		1	1					1									1			
March	1	1			1			1							1					1	
April	2			1													1				
May		1				1	1				1										
June	2	1	1	1	1				2												
July	2	2	1	2																	
August	3	1		1																	
September	3			2																	
October	1	1								1	1										
November	1	1								1	1			1			1				
December	1										1	2	1								
Total number	18	8	4	9	3	3	1	2	3	2	4	2	1	1	1		2	1		1	1

1837.

January				1						1											
February	1		2					1					1								
March	2					1			1						1						
April					1		1									1			1		
May	1	1	1	2	1		1		1							1					21
June	1						1			1	1										
July	2	1			1	1															
August	1		1	2					1												
September																					
October				1					1												
November	1				2				1												
December								1										1			
Total number	9	2	4	6	5	2	3	2	5	2	1		1		1	2		1	1		1

1838.

	DEPTHS IN TENTHS OF AN INCH.																		Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January			2							2											
February	1		2		1	2															
March		1			1					2											
April		2	1	1			1			1											
May	1	1	2	1	1						1										
June		2	1			1	1								1						
July	2	3																			
August	1				1				1												21
September			1	1		1			1					1							32
October	1	2		2			1			1						1					
November	1	1		1							1									1	
December		1	1			1															
Total number	7	13	10	6	4	5	3		2	6	2			1	1	1				1	2

1839.

January		1				1															
February		2	2			1															
March			1										1								
April	1		1	2																	25
May		1	1	3																	22
June		1	1	1		1			1												
July	2	1	1			1		1			1										22
August	1								1	1											30
September					1									1							
October			1						1												26
November				1						2											
December		1						1			1				2						
Total number	4	7	8	7	1	4		2	3	3	2		1	1	2						5

1840.

January	1	1						1								1		1			
February					1											1					
March		1						1		1						1					
April			1											1				1			
May			1		1		1			2											
June			1						1								1				
July		1	1			1		1								1					
August	1		1	2							2										
September			3		1		1			1											
October		2	1																		24, 22
November	1			1	1			1		1		1			1						
December	1	1	1					2			1										
Total number	4	6	10	3	4	1	2	6	1	5	3	1		1	1	3	1	2			2

1841.

	DEPTHS IN TENTHS OF AN INCH.																			Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January		1					2	1	1			1								1	
February			1										1								
March		1	3					1		1											
April		1	1			1		1		1								1			33
May	1		1		1								1								
June		1	1		1																
July	3	1	1			1												1		1	
August		1	1								1			1							22
September			1				1							1							
October							1														25
November		2		1		1		1		1				1							
December	2						2					1	1						1		
Total number	6	8	10	1	2	3	6	4	1	3	1	2	3	3				2	1	2	3

1842.

January	1		2				1														
February	2					1			1	1				1							
March			1		2			1													
April		1			1	1	1														
May	3						3			1											
June			2			1				2										1	45
July		2				2															
August		1	2		1			1					1								
September				1						1											
October				1				1													
November			1	1	1			2			1										
December			1			1	1			1			1								
Total number	6	4	9	3	5	6	6	5	1	6	1		2	1						1	1

1843.

January			1	1																	
February			1				1			1	1										22
March	1					1		2													33
April			1	1			1			1										1	
May				1											1	1					
June			2					2													
July	1		1												1						
August			1			1							1							1	21
September				1														1			
October				1								1	1				1			1	
November		1	1						1												
December		1	1							1					1						
Total number	2	2	9	5		2	2	4	1	3	1	1	2		3	1	1	1		3	3

1844.

	DEPTHS IN TENTHS OF AN INCH.																			Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January		1				1				1											25
February			2	1						1											
March			1		2			2												1	
April	2				1																
May	2	1	2		2																
June		2						1													
July					1	1	1			1							1				
August				1			1														
September			1			1			1	1											
October						2							1	1					1		
November	1		2							1						1					
December		1	2		1			2													
Total number	5	5	10	2	7	5	2	5	1	5			1	1		1	1		1	1	1

1845.

January		1			1					1					1						
February	1							1	1	1											
March		1	1					1		1			1								
April	1	1		1	1						1										
May	4		1							1			1								
June	2	2	1	1	1	1															
July			3	1		1						1									
August		2											1		1						25
September			2		1	1															
October					1			2					1								
November		1		1	1	1			1	1							1				39
December		1	2										1		1						
Total number	8	9	10	4	6	4		4	2	5	1	1	5		3		1				2

1846.

January		1						1	1												
February			2												1						
March	1													2							
April		1	1										1								
May			2		1	1	1	1						1							
June			1	3																	
July		1	1							1											
August	1			1	2	1		1													
September										1				1							
October			1				1		1												
November		1		1	1	1	1				1	1									
December							2	1		1											
Total number	2	4	8	5	4	3	5	4	2	3	1	1	1	4	1						

1847.

	DEPTHS IN TENTHS OF AN INCH.																			Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January		1					1			1			1					1			
February																					
March	1		1																		
April		1																			
May			3									1									
June	1		1	1	2	1			1		2					1					
July	1			1		1						1									
August							1														49
September	1					1			1											1	24, 25
October								1				1									
November						1				1											41
December		2					1	1					1	1	1						
Total number	4	4	5	2	2	4	3	2	2	2	2	3	2	1	1	1		1		1	4

1848.

January					1	1							1							25
February		1					1													30
March		1	1		1										1					
April					2															
May								1	1				1							21
June				1		1														29
July	1	1	2		1	1														
August		1	1																	32
September			2																1	
October	1	1			1															33
November	1			1	1					1								1		
December	1		1	1	3			1	1											
Total number	4	5	7	3	10	3	1	2	2	1			2		1			1	1	6

1849.

January	1	1			1															
February		1		1																
March		1				1														21, 31
April	1	1	1								1									
May	1	1	2	1			1								1					
June	2		1	1	1															
July		1	2									1								
August		4	1			1												1		
September			1		1		1	1		1										
October					2			1	1			1								28
November								1								1				
December	1		1		1			2			1									
Total number	6	10	9	3	6	2	2	5	1	1	2	2			1	1		1		3

1850.

	DEPTHS IN TENTHS OF AN INCH.																		Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January			1		2					1		1									21
February							1						1		1						
March			1		2					1				1		1					
April	1				2												1		1		
May	1	2			1		1				1										22
June	2			1						2											
July	1	1		1				1		1											
August	1		2		1													1			23, 25
September			1					1												2	
October		1						1				1									
November									1			1									
December			1		1		1						1	1			1				
Total number	6	4	6	2	9		3	3	1	5	1	3	2	2	1	1	2	1	1	2	4

1851.

January			1			1				1											
February										1				1	1						
March										2											
April								1		1	2					1					23
May		1	1								1									1	
June				1				2													
July			1	1		3			2	1											
August	1	1		1	1	1		1					1								
September	1		2	1		1			1												
October		1						1			1	1									
November		1	1				1										1				23
December					1				1				1								
Total number	2	4	6	4	2	6	1	5	4	6	4	1	2	1	1	1	1			1	2

1852.

January	1					1		1				1									
February			3					1						1							
March			1						1	1					1						
April	1											1		1			1				24
May																				1	
June		2	1		1																
July		1					1	1													
August		1	1		1			1	1			1		1							29
September		1											1								
October	1	1								1											
November			1		1	1	1														25
December			1						1				2								
Total number	3	6	8		3	2	2	4	3	2		3	3	3	1		1			1	3

1853.

	DEPTHS IN TENTHS OF AN INCH.																		Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January			1						1						1	1					
February		1		1		1				1				1							23
March		1		1				1													
April		1	1	1	2				2						1						
May								1		1	2	1									
June	1	1				1															
July				1		1		2	1		1								1		
August			1	1	1							1		1			1				30
September			1			1	1			1			1								
October			1	1										1							21
November	1	1	1											1							25
December						1			1												25
Total number	2	5	6	6	3	5	1	4	5	3	3	2	1	4	2	1	1		1		5

1854.

January			4					1													
February			1		1	1									1					1	
March				1						1					1						
April				1		1	1			1			1								25
May		1		2									1	1							
June		1		1										1				1			
July								1									1				
August	3																				
September					2		1				1										35
October	1			1	1				1												
November	1				1	1				1	1										60
December												1									22
Total number	5	2	5	6	5	3	2	2	1	3	2	1	2	2	2		1	1		1	4

1855.

January		1					1	1			1										40
February													1								28
March	1	1	1			1															
April						1		1				1									
May				1	1	1					1										
June		2	1			1	1														
July	1	4	2				1									1					
August		1				1						1									
September			1																		
October		2	1					1		1			1					1			
November			1			1		1													22
December		1					1		1		1				1			1			
Total number	2	12	7	1	3	5	4	3	1	2	2	2	2		1	1		2			3

1856.

	DEPTHS IN TENTHS OF AN INCH.																		Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January			1							1					1						25
February	1		1		1																
March		1			1				1												
April	1		1	1			1							1							
May	2							2													24
June			1	2		1				1											
July	1		1	1			1						1			1					
August	1				2			1					1								26
September	1		1							1					1						23
October			1	1	1																
November	1			1	2	1															
December						1		1			1	1									23
Total number	8	1	7	6	7	3	2	4	1	3	1	1	2	1	2	1					5

1857.

January	2	1										1		1							25
February		1	1				1						1								
March		1			1			2				1									
April					2	1													1		28
May				1	1		2			1		1									
June			1	1	1			1													
July	1	1	3			1	1			1											
August	2	2		1				1		1	1	1									
September		1	1			1						1									
October			1				1												1		
November	1			1		1	2														
December			1	2				1		1	1			1							
Total number	6	7	8	6	5	4	7	5		4	2	5	1	2					1	1	2

1858.

January	1		1									1	1				1				
February	1		1								1	1									
March					1		1		1												
April		1	1	1				1		1	1										
May		2								2											
June	2	1	2														1				30
July		2	1	1	1									1							21
August		2	1		2										1						25, 27
September		1	1					1											1		
October		1	1								1	1									
November								1				1	1								
December	1		1	1	1					1		1									
Total number	5	10	10	3	5		1	3	1	4	1	2	5	2	1		2		1		4

1859.

	DEPTHS IN TENTHS OF AN INCH.																		Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January	1				1	1									1						31
February	2	2	1	1			1														
March	1	1			1					1	1	1		1							25
April			1		2						1										
May											1										24
June	4	1	1			3															46
July	1	2		2																	
August		1		1	1			2				1									
September	1											1									24
October	1				1															1	
November	1		1			2	1														
December			1		1			2			1										
Total number	12	7	5	4	7	6	2	4		1	4	3		1	1					1	5

1860.

January	2	1	1	1																	
February	2			1	1	1			1	1											
March	2		1				1	1													
April	2	1	1	1	1																
May		1	1	1			1														
June	4					1							1					1			
July	3		1		2	1					1										
August	3	1			1	1		1	1												26
September							1		1		1		1			1					
October	3	1		1	1		1														
November	1	1		2				1	1				1								
December				1		1		1							2						
Total number	22	6	5	8	6	5	4	4	4	1	2		3		2	1		1			1

1861.

January			3	1					1			1				1					
February	2	1	1	1				1				1									
March	1	1				1					1	1			1						
April	2	2					1						1								21, 31
May	3	2			1				1				1								
June	3	3		1																	35
July	2	2	3				1														
August	1		1						1	1											24
September		1		2	1									1							
October			1	2	2		1														
November	1	2				1		1							1						
December		1											1								
Total number	15	15	9	7	4	2	3	2	3	1	1	3	3	1	2	1					4

1862.

	DEPTHS IN TENTHS OF AN INCH.																		Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January		1			2		1						1								30
February	3	1	1	1				1					1								
March			1		1										1				1		
April					1						1										
May		1		1						1	1										
June	4				1				1												51
July	3		1	1							1				1						
August	2		1		2																
September	1									1			1								23, 28
October	1			1	1							1									27
November	1	2		2	1																21, 31
December	1						1							1							
Total number	16	5	4	6	9		2	1	1	2	3	1	3	1	2				1		7

1863.

January	1	1	1		1		1					1						1			
February			2			1				1								1			
March	1		3				2	2				1									
April				1			1						1								32
May		1		1	1								1								
June	1	1	1	1						1											
July	3	1	3			1						1									21, 21, 21
August	2				1				1						2						
September	2	1	1							1											
October	1			1	1				1		1										
November	2							1							1						25, 26
December									1	1		1									26
Total number	13	5	11	4	4	2	4	3	3	4	1	4	2		3			2			7

1864.

January			2													1					25
February						1		1													
March			1		1	1						1							1		
April		1			1												1				
May	3				1	2	1														
June	1	1						1													
July			1	1			1														
August	3	1	1																		33
September		3	1		1		1														
October	1	1		1				1					1								
November							1	1										1			
December			1	1									2				1				
Total number	8	7	7	3		4	4	4	4			1	3			1	2	1		1	2

1865.

	DEPTHS IN TENTHS OF AN INCH.																			Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January				1	1		2							1		1					
February															1						40
March					1							1						1			21
April	1				1		1		2												
May	1				1				1											1	28
June		1												1							
July	2		1	1			1				1	1									
August		2	1																		
September	1	1																			
October		1	2		1											1	1				
November					1											1			1		
December	1	1	1	1	1		1		1	1											
Total number	6	6	5	3	7		5		4	1	1	2		2	1	3	1	1	1	1	3

1866.

January				1	1					1											
February		1				1	1									1					26
March			1				1	1	1								1				
April	2	1		1	1		1														
May		2			1	1	1						1				1				
June		3	1					2			2										
July	1	2	2	1		1															
August	1	1	1	2		1	1														
September	1		1			1	1			3		1									
October	3	1							1						1						
November			1	2	1																24
December			2		1			1		1	1										
Total number	8	11	9	7	5	5	6	4	2	5	3	1	1		1	1	2				2

1867.

January			1	1				1				1									30
February		4	1				1				1										42
March	1			1	1	1			1		1							1			
April	2	2	1	2	1																
May	1		2	1						1									1		
June					2	1															
July	1	2	1		1			1			1										
August		1						1	1	1											21, 33
September	1		2																		
October		2														1					22
November	2	2			1		1		1												
December	2	4		1	1						1										
Total number	10	17	8	6	7	2	2	3	3	2	4	1				1		1	1		5

1868.

	DEPTHS IN TENTHS OF AN INCH.																				Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January			1		2				1		1		1								
February		2				1	1														
March				1		2									2						
April	1	4				2					1										32
May	1					1				1	1	1									23, 43
June			2					1						1			1				
July	1	1				1							1								
August		1				1						1									26
September	1	1	2		1	1		1				1									22
October		2							1												
November		1						1		1	1		1								
December	2	1		1			1				1										
Total number	6	13	5	2	3	9	2	3	2	2	5	3	3	1	2		1				5

1869.

January									1						1	1					
February			1				1	1			1										24
March		1			1	1			2					1						1	
April				1			1			1											
May					1	3								1	1						
June			1	1	2			2	1					1							
July	1		3																		
August	1			1	1	1															
September	1			1		1								1							26
October		1						1		1						1					23
November		1		2		1			1												
December	1									1					1						21
Total number	4	3	5	6	5	7	2	4	5	3	1			4	3	2				1	4

1870.

January			1	2					1					1					1		23
February						1	1			1		1									
March	2							1			1						1	1			
April		3				1			1												25
May						1		1				1									
June					1	1									1						32, 25
July		2		1												1					
August			1											1							
September	1		3															1			
October				1			2						1								26
November				1	1															1	
December	1					2		1		1											
Total number	4	5	5	5	2	6	3	3	2	2	1	1	1	2	1	1	1	2	1	1	5

1871.

	DEPTHS IN TENTHS OF AN INCH.																			Depth of Rains greater than 2 inches.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
January	2								1				1								
February			1				1	1		1	1										
March	1	1	1		2	1	1														24
April					1		1			1						1					
May		2			1																30
June					1	2			1			1							1		
July	1		1			1		1										1			
August				1		1				2			1		1						
September	1								1												
October									1		1										47
November			1			1						1	1								
December		1	1		2									1							
Total number	5	4	5	1	7	6	3	2	4	4	2	2	3	1	1	1		1	1		3

1872.

January		1			1													1			
February						1				1											
March			1	1		1	1			2		1									
April		1	1	2							1										
May	2	1			1	1				1			1								
June	1			1	2	1					1										
July	2	1	2		1	1						1								1	
August	1	1	1			1			1					1							28
September							1	1				1		1					1		
October	1	1		1								1		1							21
November		2		3																	35
December	2	1		3									1								
Total number	9	9	5	11	5	6	1	1	2	4	2	4	2	3				1	1	1	3

1873.

January					2	1		1							1			1			
February			1					1										2			
March	1		1		2		1	1	1												
April		2			1	1														1	
May			2		1												1	1			
June		1	1																		23
July		2			1	1	1	1													
August		2	1	1							1								1		39
September	1	2	1												1						
October										1					1						24
November	1						1						1	1				1			
December			1	1															1		24
Total number	3	9	8	2	7	3	3	4	1	1	1		1	1	3		1	5	2	1	4

The following table gives the number of storms in each year, classified according to the depth of rain; also the number of rainy days in the year. The number of days is greater than the number of storms.

	DEPTHS IN TENTHS OF AN INCH.																																						Depths of Rains greater than 4 inches.	Number of rainy days.	Days omitted.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40			
1832.....	16	8	5	9	3	8	3	4	1	3	1	1			3	1		2			1		1																		85	0
1833.....	11	9	4	8	5	3	3	3	2	3	1	1	3			1			1					1		1															63	10
1834	12	9	7	4	7	3	2	4		1			3		2	1			2							1			1											70	66	0
1835.....	9	9	13	2	5	7	1	3	2	1	1	2	1		1	2								1																	64	2
1836.....	18	8	4	9	3	3	1	2	3	2	4	2	1	1	1		2	1		1					1																69	0
1837.....	9	2	4	6	5	2	3	2	5	2	1		1		1	2		1	1		1																				58	1
1838	7	13	10	6	4	5	3		2	6	2			1	1	1				1	1											1									61	0
1839.....	4	7	8	7	1	4		2	3	3	2		1	1	2							2			1	1				1											58	0
1840.....	4	6	10	3	4	1	2	6	1	5	3	1		1	1	3	1	2				1		1																	95	3
1841.....	6	8	10	1	2	3	6	4	1	3	1	2	3	3				2	1	2		1			1								1								116	4
1842.....	6	4	9	3	5	6	6	5	1	6	1		2	1						1																				45	103	9
1843.....	2	2	9	5		2	2	4	1	3	1	1	2		3	1	1	1		3	1	1											1								96	0
1844.....	5	5	10	2	7	5	2	5	1	5			1	1		1	1		1	1					1																101	7
1845.....	8	9	10	4	6	4		4	2	5	1	1	5		3		1								1															1	93	17
1846.....	2	4	8	5	4	3	5	4	2	3	1	1	1	4	1																										104	10
1847.....	4	4	5	2	2	4	3	2	2	2	2	3	2	1	1	1		1		1				1	1															41, 49	102	7
1848....	4	5	7	3	10	3	1	2	2	1			2		1			1	1		1				1				1	1		1	1							91	15
1849.....	6	10	9	3	6	2	2	5	1	1	2	2			1	1		1			1							1			1									102	0
1850.....	6	4	6	2	9		3	3	1	5	1	3	2	2	1	1	2	1	1	2	1	1	1		1																122	0
1851.....	2	4	6	4	2	6	1	5	4	6	4	1	2	1	1	1	1			1			2																		117	0
1852.....	3	6	8		3	2	2	4	3	2		3	3	3	1		1			1				1	1			1													120	3

| | | |

The following table gives every storm of which the time of beginning and ending was recorded, and the rate of rainfall per hour during that time: —

Date.	Hours.	Am't.	Rate.	Date.	Hours.	Am't.	Rate.
Dec. 6, 1834...	5	1.50	0.30	July 7, 1841...	1	0.20	0.20
" 29,30, " ...	13	1	0.077	" 14, " ...	2	2.00	1.00
Feb. 6, 1835...	9	0.10	0.011	Sept. 4, " ...	2	0.30	0.15
Mar. 9, " ...	2	1.50	0.75	Nov. 12, " ...	6	0.60	0.10
" 10, " ...	9	0.75	0.08	" 29, " ...	16	1.00	0.063
" 22, " ...	16.5	1.15	0.07	Dec. 14, " ...	6	0.70	0.12
" 30, " ...	15.5	0.55	0.035	Apr. 7, 1842...	3.5	0.24	0.07
Apr. 13, " ...	3.5	0.03	0.01	May 11, " ...	3	0.68	0.23
" 16, " ...	11	0.45	0.04	Aug. 12, " ...	3	0.52	0.17
" 22, " ...	5	0.28	0.06	" 14, " ...	1	0.20	0.20
"25,26, " ...	26	0.85	0.03	" 18, " ...	1	0.25	0.25
" 28, " ...	6.5	0.85	0.13	" 29, " ...	1	0.25	0.25
May 14,15, " ...	21.5	0.25	0.01	Sept. 25, 1843...	2	1.80	0.90
June 5, " ...	2	0.45	0.23	Mar. 4, 1844...	10	0.75	0.08
" 10, " ...	3	0.20	0.07	Apr. 9,10, " ...	3.5	0.50	0.14
July 25, " ...	1	0.18	0.18	" 24, " ...	2.5	0.07	0.03
" 31, " ...	1	0.15	0.15	May 21, " ...	1	0.30	0.30
Aug. 3, " ...	1	0.10	0.10	" 27, " ...	1	0.10	0.10
" 21, " ...	1	0.15	0.15	June 9, " ...	1	0.15	0.15
" 28, " ...	12	0.35	0.03	" 22, " ...	4	0.80	0.20
Sept. 20, " ...	5.5	0.25	0.05	July 11, " ...	2	0.56	0.28
Jan. 18, 1836...	3	0.75	0.25	" 16, " ...	8	1.70	0.22
"24,25, " ...	13.5	2.50	0.17	Sept. 1, " ...	5.5	0.90	0.16
Feb. 7, 8, " ...	18	1.75	0.097	Nov. 11, " ...	1	0.27	0.27
June 17, " ...	0.25	0.90	0.90	May 25, 1845...	1	0.05	0.05
Sept. 29, " ...	15.5	0.35	0.02	June 21, " ...	4	0.30	0.08
Nov. 2, 3, " ...	20	1.65	0.08	" 24, " ...	1	0.35	0.35
" 12, " ...	4.5	1.05	0.23	Oct. 9, " ...	1	0.50	0.50
" 15, " ...	3	0.15	0.05	Nov. 27, " ...	9.5	3.85	0.41
" 21, " ...	7.5	0.95	0.13	Feb. 20, 1846...	11.5	0.33	0.03
May 5, 1837...	3	0.42	0.14	May 18, " ...	1	0.50	0.50
" 6, " ...	2	0.14	0.07	" 23, " ...	3	1.43	0.48
July 24, " ...	2.5	0.45	0.18	June 15, " ...	1	0.35	0.35
Aug. 3, " ...	2	0.85	0.43	July 11, " ...	1	0.28	0.28
Dec. 10, " ...	3.5	0.75	0.22	Aug. 8, " ...	2	0.35	0.18
June 14, 1838...	1	0.25	0.25	" 10, " ...	2	0.45	0.23
" 17, " ...	1	0.20	0.20	" 14, " ...	1	0.10	0.10
" 22, " ...	1	0.65	0.65	Sept. 8, " ...	2	1.37	0.685
" 25, " ...	1	0.60	0.60	" 12, " ...	2	0.96	0.48
July 5, " ...	1	0.05	0.05	Feb. 3, 1847...	11.5	0.96	0.08
Aug. 6, " ...	1	0.90	0.90	June 29, " ...	4	0.90	0.23
" 25, " ...	6.5	2.05	0.32	July 13, " ...	1	0.08	0.08
Oct. 24, " ...	16	0.95	0.06	Nov. 14, " ...	18.5	1.00	0.05
Dec. 8, " ...	3	0.30	0.10	" 19, " ...	7	0.62	0.09
" 22, " ...	4.5	0.15	0.03	Ap.13,14, 1848...	6	0.45	0.075
May 29, 1839...	1	0.25	0.25	July 5, " ...	1	0.60	0.60
July 7, " ...	1	0.15	0.15	Mar. 15, 1849...	4	0.55	0.14
" 11, " ...	1	0.62	0.62	Apr. 20, " ...	1	0.10	0.10
" 18, 1840..	2	0.81	0.41	June 4, " ...	1.5	0.37	0.24
" 24, " ...	2	1.55	0.77	Aug. 12, " ...	5.25	0.56	0.106
Ap.12,13, 1841...	20	1.75	0.087	Dec. 19, " ...	3	0.27	0.09
May 23, " ...	1	0.33	0.33	" 20, " ...	1	0.10	0.10
July 1, " ...	1.5	0.33	0.22	Jan. 18, 1850...	8	1.00	0.125
" 5, " ...	1	1.75	1.75	" 25, " ...	5	0.30	0.06

Date.	Hours.	Am't.	Rate.	Date.	Hours.	Am't.	Rate.
Feb. 14. 1850...	6	1.28	0.21	Sept. 15, 1854...	2	0.45	0.23
Mar. 23, " ...	13.5	1.00	0.08	Oct. 3, " ...	5	0.40	0.08
Apr. 12, " ...	5	0.10	0.02	May 24, 1855...	2	0.60	0.30
" 13, " ...	4	0.45	0.11	June 30, " ...	2	0.70	0.35
June 25, " ...	1	0.10	0.10	July 5, " ...	1	0.25	0.25
July 19, " ...	8.5	1.00	0.12	" 18, " ...	1	0.15	0.15
" 28,29, " ...	2.5	0.75	0.30	" 31, " ...	1	0.10	0.10
Aug. 4, " ...	3	0.30	0.10	Aug. 4, " ...	1.5	0.62	0.42
" 6, " ...	2.5	2.25	0.90	Sept. 27, " ...	3	0.25	0.08
" 7, " ...	1	0.25	0.25	Dec. 9, " ...	13	1.75	0.13
" 13,14, " ...	11.5	1.80	0.15	Mar. 6, 1856...	4	0.20	0.05
" 25, " ...	11	2.50	0.23	June 4, " ...	1	0.25	0.25
Sept. 3, " ...	5	2.00	0.40	" 9, " ...	2	0.55	0.28
" 7, 8, " ...	28.5	2.00	0.08	" 27, " ...	1	0.37	0.37
Sept. 27, " ...	1	0.75	0.75	July 6, " ...	1	0.65	0.65
May 20, 1851...	1	0.15	0.15	" 22, " ...	2	0.30	0.15
July 25, " ...	1	0.60	0.60	Aug. 8, " ...	2	1.25	0.63
" 26, " ...	1	0.37	0.37	" 17, " ...	1	0.50	0.50
Aug. 9, " ...	2	1.25	0.63	Sept. 11, " ...	1	0.30	0.30
Sept. 2, " ...	1	0.60	0.60	" 13, " ...	1	0.10	0.10
" 21, " ...	1	0.10	0.10	May 31, 1857...	2	0.35	0.18
Nov. 2. " ...	4	0.25	0.06	July 21, " ...	1	0.10	0.10
Dec. 15, " ...	4.5	0.50	0.11	Sept. 6, " ...	1	0.20	0.20
Mar.24-5, 1852....	9	0.85	0.09	June 6, 1858...	1	0.25	0.25
June 20, " ...	1	0.20	0.20	" 21, " ...	1	0.30	0.30
" 22, " ...	1	0.25	0.25	July 11, " ...	3	1.35	0.45
July 2, " ...	1	0.20	0.20	" 22, " ...	1	0.35	0.35
" 26, " ...	11	0.78	0.07	Aug. 1, " ...	3	0.25	0.08
Aug. 7, " ...	1	0.87	0.87	" 17, " ...	2	0.20	0.10
" 10, " ...	2	0.50	0.25	" 18, " ...	1	0.45	0.45
" 15, " ...	1	0.25	0.25	Sept. 4, " ...	2	0.80	0.40
Nov. 12, " ...	6	0.60	0.10	Mar. 12, 1859...	6	1.10	0.18
Feb. 3, 1853...	2	0.60	0.30	June 10, " ...	4	0.25	0.06
" 7, " ...	3	0.15	0.05	" 29, " ...	1	0.62	0.62
July 9, " ...	2	0.60	0.30	July 22, " ...	1	0.12	0.12
" 16, " ...	4	0.40	0.10	" 25, " ...	2	0.35	0.175
Nov. 24, " ...	1	0.10	0.10	Sept. 13, " ...	1	0.10	0.10
May 5, 1854...	2	0.20	0.10	Oct. 14, " ...	1	0.12	0.12
June 28, " ...	1	0.20	0.20				

In twenty-six years previous to 1860, the time of rainfall is recorded in 185 storms: —

In 131 storms,	rain	fell	at	the	rate	of	0.25	inch	per hour, or less.
" 18	"	"	"	"	"	0.33	"	"	about.
" 9	"	"	"	"	"	0.40	"	"	"
" 7	"	"	"	"	"	0.50	"	"	"
" 8	"	"	"	"	"	0.62	"	"	"
" 3	"	"	"	"	"	0.67	"	"	"
" 3	"	"	"	"	"	0.75	"	"	"
" 4	"	"	"	"	"	0.87	"	"	"
" 1	"	"	"	"	"	1.00	"	"	"
" 1	"	"	"	"	"	1.75	"	"	"
185									

The two storms giving 1 inch and 1¾ inch per hour fell on the 5th and on the 14th of July, 1841.

In one case, where the time of rainfall was less than an hour, the rate is made as though the rain was an hour in falling.

Date.	Hours.	Am't.	Rate.	Date.	Hours.	Am't.	Rate.
April 6, 1860...	1	0.30	0.30	Dec. 24, 1865...	12	1.01	0.08
" 17, " ...	3	0.10	0.03	Jan. 26, 1866...	1.5	1.03	0.68
June 7, " ...	3	0.12	0 04	April 22, " ...	1	0.21	0.21
Aug. 22, " ...	7	2.55	0.36	July 18, " ...	1	0.09	0.09
Sept. 20, " ...	6	0.85	0 14	" 27, " ...	3.5	0.39	0.11
Nov. 12, " ...	1	0.15	0.15	Sept. 4, " ...	2	0.99	0.49
"23, 24, " ...	12	0.85	0.07	" 8, " ...	3	0.95	0.32
Dec. 22, " ...	14	1.47	0.11	Dec. 4, " ...	2	0.33	0.16
"30, 31, " ...	17	0.37	0.02	Jan. 17, 1867...	15	3.00	0.20
Jan. 18, 1861...	4	0.40	0.10	Apr. 1, " ...	6	0.41	0.07
" 24, " ...	6	1.10	0.18	" 5, " ...	9	0.26	0.03
"26, 27, " ...	16	0.30	0.02	" 22, " ...	1	0.24	0.24
Mar. 9, " ...	8	1.10	0.14	" 27, " ...	3	0.11	0.04
"21, 22, " ...	25	1.45	0.06	July 4, " ...	1.5	0.48	0.32
" 27, " ...	11	0.57	0.05	Aug. 2, " ...	3	1 20	0.40
Apr. 1–3, " ...	41	2.12	0.05	" 2, " ...	4	2.10	0.52
" 30, " ...	2	0.10	0.05	Oct. 15, " ...	1	0.18	0.18
May 4, " ...	3	0.15	0.05	Nov. 16, " ...	3	0.15	0.05
" 25, " ...	1.5	0.05	0.03	Dec. 10, " ...	5	0.20	0.04
" 27, " ...	14	0.45	0.03	" 20, " ...	6	0.12	0.02
" 29, " ...	11	0.12	0.01	" 26, " ...	5	0.35	0.07
June 23, " ...	1	0.03	0.03	Jan. 23, 1868...	8	0.54	0.07
" 29, " ...	1	0.07	0.07	Apr. 7, " ...	13	3.20	0.25
July 17, " ...	1	0.12	0.12	" 16, " ...	1	1.12	1.12
Aug. 5, " ...	1	0.85	0.85	June 9, " ...	1	0.25	0.25
Nov. 3, " ...	17.5	1.45	0.08	June 17, " ...	2	1.44	0.72
May 19, 1862...	3	0.20	0.07	July 5, " ...	1	0.58	0.58
June 4, " ...	1	0.50	0.50	Aug. 20, " ...	3	0.56	0.18
" 5, " ...	18	4.60	0.25	Sept. 13, " ...	1	0.25	0.25
" 27, " ...	1	0.10	0.10	" 16, " ...	1	0.10	0.10
" 30, " ...	1	0.45	0.45	Nov. 26, " ...	5	0.83	0.17
July 2, 3, " ...	15	1.10	0.07	Dec. 7, " ...	12	0.67	0.06
" 9, " ...	4	0.10	0.02	Mar. 15, 1869...	9	0.60	0.07
Aug. 9, " ...	1.5	0.05	0.03	" 23, " ...	8	0.85	0.11
Sept. 28, " ...	1	2.00	2.00	Apr. 29, " ...	15	0.65	0.04
Nov. 17, " ...	7	0.40	0.06	May 2, " ...	1	1.40	1.40
Jan. 10, 1863...	6	0.65	0.11	" 26, " ...	1	0.50	0.50
Feb. 3, " ...	7	0.03	0.004	July 11, " ...	1.5	0.32	0.23
"22, 23, " ...	20	1.00	0.05	" 14, " ...	1	0.26	0.26
May 12, " ...	0.50	0.21	0.21	" 16, " ...	2	0.05	0.03
July 25, " ...	4	0.29	0.07	Sept. 7, " ...	3.5	0.60	0.14
" 26, " ...	3	2.08	0.70	Jan. 8, 1870...	8	0.35	0.04
Aug. 16, " ...	1	1.52	1.52	Mar. 18, " ...	3	0.12	0.04
Oct. 17, " ...	2	1.07	0.53	May 10, " ...	1	1.20	1.20
Jan. 1, 1864...	16	1.61	0.10	June 14, " ...	1	0.60	0.60
July 25, " ...	5	0.75	0.15	" 17, " ...	1	3.15	3.15
Aug. 14, " ...	1	0.09	0.09	" 20, " ...	2.5	2.52	1.00
" 3–5, " ...	34	3.35	0.10	July 17, " ...	1	0.23	0.23
" 7, 1865...	1	0.30	0.30	Aug. 25, " ...	1	0.31	0.31
" 11, " ...	5	0.22	0.04	Sept. 25, " ...	2	0.11	0.05
Sept. 6, " ...	4	0.22	0.05	Oct. 12, " ...	8	0.44	0.05
Oct. 10, " ...	1	0.32	0.32	Oct. 31, " ...	5	1.25	0.25

Date.	Hours.	Am't.	Rate.	Date.	Hours.	Am't.	Rate.
Feb. 14, 1871...	10	0.95	0.09	June 8, 1872...	1	0.47	0.47
Mar. 10, " ...	4	0.53	0.13	" 14, " ...	0.50	0.50	0.50
" 21, " ...	14	2.40	0.17	July 5, " ...	1	0.22	0.22
April 2, " ...	13	1.00	0.07	" 16, " ...	2	1.16	0.58
" 21, " ...	1	0.50	0.50	" 17, " ...	3	0.25	0.08
May 22, " ...	1	0.15	0.15	Aug. 13, " ...	3	0.25	0.08
July 28, " ...	2	0.81	0.40	Sept. 19, " ...	5	0.88	0.18
" 30, " ...	1	1.83	1.83	Dec. 26, " ...	15	1.25	0.08
" 31, " ...	1	0.10	0.10	Mar. 10, 1873...	9	0.25	0.03
Aug. 8, " ...	3	1.50	0.50	April 6, " ...	3	0.24	0.08
" 16, " ...	1	0.62	0.62	" 19, " ...	2	0.18	0.09
" 30, " ...	5	0.36	0.07	June 28, " ...	1	2.32	2.32
Sept. 17, " ...	1	0.83	0.83	July 1, " ...	2	0.70	0.35
Oct. 11, 12, " ...	27.5	4.68	0.17	" 11, " ...	1	0.55	0.55
" 28, " ...	1	0.03	0.03	" 27, " ...	5	0.81	0.16
Feb. 3, 1872...	13	1.00	0.08	Aug. 3, " ...	1	0.17	0.17
April 13, " ...	3.5	0.30	0.09	" 22, " ...	5	3.90	0.78
" 22, " ...	5	0.35	0.07	Sept. 19, " ...	11	1.54	0.14
May 19, " ..	6	0.96	0.16				

4

In fourteen years, to the 1st of January, 1874, the time of rainfall is recorded in 139 storms: —

In 98 storms,	rain	fell	at	the	rate	of 0.25	inch	per hour,	or less.
" 9	"	"	"	"	"	0.33	"	"	about.
" 2	"	"	"	"	"	0.40	"	"	"
"10	"	"	"	"	"	0.50	"	"	"
" 5	"	"	"	"	"	0.60	"	"	"
" 3	"	"	"	"	"	0.70	"	"	"
" 2	"	"	"	"	"	0.80	"	"	"
" 1	"	"	"	"	"	0.90	"	"	"
" 1	"	"	"	"	"	1.00	"	"	"
" 1	"	"	"	"	"	1.12	"	"	"
" 1	"	"	"	"	"	1.20	"	"	"
" 1	"	"	"	"	"	1.40	"	"	"
" 1	"	"	"	"	"	1.52	"	"	"
" 1	"	"	"	"	"	1.83	"	"	"
" 1	"	"	"	"	"	2.00	"	"	"
" 1	"	"	"	"	"	2.32	"	"	"
" 1	"	"	"	"	"	3.15	"	"	"
139									

Of those storms giving an inch or more per hour, —

One fell in 1862.	Three fell in 1870.
" " 1863.	One " 1871.
" " 1868.	" " 1873.
" " 1869.	

Making nine such storms in fourteen years, against two in the previous period of twenty-six years. Seven of these storms occurred in the last six years.

Where the time of rainfall was less than an hour, it is reckoned as having been an hour in falling.

Dr. Caswell made special memoranda of storms which were so extraordinary as to demand it. I give below the principal facts in regard to these: —

1862, June 4 and 5. — Extraordinary rain. A heavy thunder-shower occurred between the hours of 1 and 2 on the morning of the 4th. About 9 o'clock a steady rain set in, which continued, with slight intermissions, and at times pouring heavily, till about 4, A.M., of the 5th. For eighteen hours it was a pretty steady pour of rain. The rain-gauge held, as the result of the thunder-shower, a little less than

half an inch, and for the entire rain five and one-tenth inches of water (5.10). "My impression is, that there has been but one case in this city, in a period of thirty years, in which an equal quantity of water fell in so short a time. It is worthy of note, that the barometer stood at about 30.00 inches, and fell only about a tenth of an inch during the storm." [The rate of fall per hour was a little more than a quarter of an inch in depth.]

1862, Sept. 28. — "Very heavy rain from 2 to 3, P.M., with some thunder. Nearly two inches of rain fell in the course of one hour."

1863, Aug. 16. — "Very heavy thunder-shower between 5 and 6, P.M., 1.42 inches of rain falling in about 20 minutes."

1864, Aug. 3 and 5. — "Rain. The total amount of rain which fell from midnight, Tuesday, to 10, A.M., Thursday, was 3.35 inches. In the same storm, the quantity which fell from 10, A.M., of the 3d, to 10.20, A.M., Aug. 4, at Peacedale, South Kingston, was reported to be 6.70 inches." [The rate per hour in Providence was about $\frac{1}{10}$ of an inch; in Peacedale, about $\frac{2\,8}{100}$ of an inch.]

1867, Jan. 17. — 7, A.M., to 7, P.M. "Snow, reported to be 20 to 24 inches on a level. Equal to 3.00 inches of rain."

1868, April 7. — "Began to snow at 7, A.M.; snowed till 1, P.M., when it turned to rain, and rained until 8, P.M. Total amount which fell, 3.20 inches."

1870, June 17. — "Thunder-shower between 12, M., and 5, P.M. Amount 3.15, nearly all of which fell between 12, M., and 1, P.M.; being the largest quantity I have ever known in so short a time."

1871, Oct. 11 and 12. — "Rain. Total quantity, from 7, A.M., of the 11th, to 10.30, A.M., of the 12th, 4.68 inches." [Rate per hour, $\frac{1}{8}$ of an inch.]

The following table, showing the amount of rainfall, and the rate per hour, is made up from the records kept by our employés at Hope Reservoir in this city: —

Date.	Hours.	Am't.	Rate.	Date.	Hours.	Am't.	Rate.
Mar. 26, 1873...	5.3	0.02	0.004	July 27, 1873...	1	0.30	0.30
" " " ...	2	0.23	0.11	" " " ...	0.1	0.10	0.10
Apr. 12, " ...	2.75	0.18	0.06	" " " ...	0.8	0.23	0.23
" 12,13, " ...	19½	1.62	0.09	Aug. 3, " ...	1.2	0.20	0.17
" 13, " ...	12½	0.05	0.004	" 13, 14, " ...	2.3	1.61	0.69
" 17, 18, " ...	12	0.54	0.04	" 18, " ...	3.5	0.25	0.07
" 19, " ...	0.66	0.04	0.04	" 18, 19, " ...	13.25	1.20	0.09
" " " ...	1.½	0.04	0.03	" 22, " ...	4.3	0.85	0.19
" 29, " ...	1.2	0.05	0.04	" " " ...	3	2.77	0.92
May 2, " ...	9.5	0.65	0.07	" " " ...	2.6	0.40	0.15
" 2, 3, " ...	11½	0.27	0.02	Sept. 1, " ...	0.1	0.05	0.05
" 3, " ...	4½	0.34	0.07	" " " ...	0.75	0.01	0.01
" 3, 4, " ...	10	0.29	0.03	" 4, " ...	1	0.01	0.01
" 9,10, " ...	18.5	1.60	0.09	" " " ...	0.25	0.07	0.07
" 10, " ...	11.5	0.13	0.01	" " " ...	0.6	0.01	0.01
" 12, " ...	0.5	0.03	0.03	" 19, " ...	4.25	0.90	0.21
" 21, 22, " ...	6	0.23	0.04	Oct. 20, " ...	0.6	0.01	0.01
" 24, " ...	15	0.25	0.02	" " " ...	0.6	0.05	0.05
June 7, " ...	1	0.07	0.07	" " " ...	2.2	0.05	0.02
" 11, " ...	1.5	0.17	0.12	" " " ...	1.2	0.05	0.04
" 28, " ...	0.5	0.02	0.02	" 27, " ...	7.25	0.60	0.08
" " " ...	3.0	2.38	0.79	" " " ...	3.6	0.45	0.12
July 1, " ...	0.5	0.13	0.13	Nov. 7, 8, " ...	3.25	1.60	0.49
" " " ...	2	0.66	0.33	" 17, 18, " ...	14	0.93	0.07
" 11, " ...	0.2	0.02	0.02	" 18, " ...	2.2	0.05	0.02
" " " ...	0.3	0.01	0.01	" 25, " ...	2.3	0.01	0.004
" " " ...	0.7	0.59	0.59	Dec. , " ...	7.0	0.10	0.01
" " " ...	0.2	0.04	0.04	" 9, " ...	3.8	0.15	0.04
" 17, " ...	2.3	0.02	0.01	" 11, " ...	4.2	0.075	0.02
" " " ...	1	0.20	0.20	" " " ...	2.6	0.05	0.02
" " " ...	2	0.03	0.015	" 26, " ...	13.5	0.75	0.05
" " " ...	0.7	0.15	0.15	" 27,28 " ...	16.25	0.45	0.03
" 27, " ...	0.75	0.30	0.30				

Where the time of rainfall was less than an hour, it is reckoned as having been an hour in falling.

The following table of rainfall, and rate per hour, is made up from the records kept by our employé at Sockanosset Reservoir in Cranston: —

Date.	Hours.	Am't.	Rate.	Date.	Hours.	Am't.	Rate.
Apr. 2, 1873...	7.1	0.43	0.06	Aug. 20, 1873...	0.5	0.08	0.08
" 6, " ...	2.9	0.28	0.09	" 22, " ...	17	1.25	0.07
" 9, " ...	5	0.10	0.02	" 23, " ...	1	0.25	0.25
" 12,13, " ...	2.3	1.50	0.65	" 23, " ...	0.2	0.08	0.08
" 17,18, " ...	9.2	0.76	0.08	" 30, " ...	3.1	0.42	0.14
" 19, " ...	3.9	0.06	0.01	" 31, " ...	2.5	0.50	0.20
May 2, " ...	14.8	0.89	0.06	Sept. 1, " ...	0.25	0.12	0.12
" 3, " ...	9.2	0.66	0.07	" 4, " ...	5.5	0.20	0.03
" 9, " ...	8	2.62	0.33	" 14, " ...	4.5	0.12	0.03
" 11, " ...	13.8	0.49	0.03	" 19, " ...	8.7	1.62	0.19
" 13, " ...	0.6	0.06	0.06	" 23, 24, " ...	10.5	0.32	0.03
" 17, " ...	5.2	0.01	0.002	" 29, 30, " ...	5	0.20	0.04
" 21, 22, " ...	6.7	0.25	0.04	Oct. 5, " ...	1.3	0.20	0.15
" 24, " ...	0.25	0.28	0.28	" 7, " ...	6.5	1.30	0.20
June 7, " ...	12.9	0.60	0.05	" 7, " ...	12.5	0.70	0.05
" 11, " ...	0.1	0.20	0.20	" 19, " ...	3.75	0.30	0.09
" 28, " ...	2.0	1.00	0.50	" 20, " ...	17	1.10	0.06
July 1, " ...	2.1	0.17	0.08	" 27, " ...	13.5	0.75	0.06
" 1, " ...	4.8	0.11	0.02	Nov. 7,8, " ...	14.25	1.55	0.11
" 11, " ...	0.75	0.64	0.64	" 12, " ...	5.75	0.74	0.13
" 17,18, " ...	13.25	0.33	0.02	" 16, " ...	5	0.24	0.05
" 19, " ...	3.75	0.21	0.06	" 17,18, " ...	27	1.05	0.04
" 27, " ...	3.1	1.60	0.52	" 24, " ...	12.25	2.20	0.17
" 28, " ...	1.1	0.25	0.23	Dec. 5, " ...	2.75	0.30	0.11
" 30, " ...	0.6	0.02	0.02	" 9, " ...	6.9	0.22	0.03
Aug. 1, " ...	1.1	0.25	0.23	" 12, " ...	3.75	0.70	0.19
" 3, " ...	0.75	0.20	0.20	" 13, " ...	8	1.90	0.24
" 14, " ...	23	2.45	0.11	" 23, " ...	5	0.10	0.02
" 18, " ...	13.25	0.25	0.02	" 26–28, " ...	47.5	1.45	0.03
" 19, " ...	17.1	1.40	0.08				

Where the time of rainfall was less than an hour, it is reckoned as having been an hour in falling.

The following table of rainfall, and rate per hour, is made up from the records kept by our employés at Pettaconset Pumping-Station in Cranston: —

Date.	Hours.	Am't.	Rate.	Date.	Hours.	Am't.	Rate.
Apr. 9, 10, 1873...	10.5	0.10	0.009	Aug. 22, 1873...	8.	1.28	0.16
" 12, " ...	7	1.37	0.20	" 30, " ...	3.2	1.68	0.53
"12, 13, " ...	31	0.26	0.009	" 31, " ...	1.75	0.28	0.16
"18, 19, " ...	13	0.76	0.06	Sept. 1, " ...	0.3	0.05	0.05
May 2, " ...	2	0.98	0.49	" 4, " ...	5.3	0.20	0.03
" 3, " ...	9	0.82	0.09	" 14, " ...	8.25	0.25	0.03
" 9, 10, " ...	26	2.42	0.09	" 19, " ...	8.5	1.60	0.19
" 11, " ...	17	0.45	0.02	" 23, 24, " ...	11.25	0.30	0.026
" 13, " ...	12.5	0.08	0.006	" 29, 30, " ...	4.5	0.20	0.04
" 21, 22, " ...	6.5	0.25	0.04	Oct. 5, " ...	4	0.20	0.05
" 24, " ...	0.5	0.30	0.30	" 7, " ...	22.25	2.25	0.10
June 7, " ...	1	0.46	0.46	" 8, " ...	2	0.08	0.04
" 11, " ...	0.25	0.18	0.18	" 19, " ...	4.5	0.36	0.08
" 28, " ...	1.8	1.00	0.67	" 20, " ...	21.5	0.94	0.04
July 1, " ...	2.9	0.25	0.08	" 27, " ...	12	1.10	0.09
" 11, " ...	0.75	0.52	0.52	Nov. 7, 8, " ...	13.5	1.65	0.12
" 17, 18, " ...	18.75	0.32	0.02	" 12, " ...	26.75	0.70	0.03
" 19, " ...	4.25	0.35	0.08	" 15, " ...	4	0.15	0.04
" 27, " ...	15.25	1.42	0.09	" 17, 18, " ...	16.25	1.10	0.06
" 28, " ...	0.75	0.15	0.15	" 24, " ...	12.25	2.10	0.17
Aug. 1, " ...	1.1	0.38	0.35	Dec. 4, " ...	4.5	0.55	0.12
" 3, " ...	0.6	0.20	0.20	" 9, " ...	19.25	0.25	0.01
" 14, " ...	10.5	2.55	0.24	" 12, " ...	18	0.70	0.04
" 18, " ...	1.25	0.18	0.14	" 13, " ...	19.75	1.90	0.09
" 19, " ...	1.75	0.72	0.41	" 23, " ...	5	0.10	0.02
" 19, " ...	0.3	0.18	0.18	" 26, 28, " ...	47.30	1.55	0.03

Where the time of rainfall was less than an hour, it is reckoned as having been an hour in falling.

Mr. Bazalgette, chief engineer to the Metropolitan Board of Works of London, says, "Careful observations of the quantity of rain falling on the metropolis within short periods have been made [by him] for many years. Taking an average of several years, it has been ascertained that there are about one hundred and fifty-five days per annum upon which rain falls: of these, there are only about twenty-five upon which the quantity amounts to a fourth of an inch in depth in twenty-four hours.

"But there are, in almost every year, exceptional cases of heavy and violent rain-storms; and these have measured one inch, and sometimes even two inches, in an hour."

Mr. R. Rawlinson says, "In Birmingham, on the evening of Sunday, the 6th of July, 1845, there fell 1.945 inch of rain in little more than half an hour. This is, no doubt, such a flood as is seldom met with; but equal volumes of rain have fallen in the metropolis and in other places in England."

Mr. Hawksley says, "In the great storm in London, in August, 1846, $3\frac{8}{10}$ inches fell in two hours and twenty minutes; and at Nottingham he had known 1.16 inch to fall in less than half an hour."

The Annual Report of Mr. John Roe, surveyor to the Holborn and Finsbury sewers, Jan. 29, 1847, contains the following, which, I suppose, refers to the storm mentioned by Mr. Hawksley: "In August last, the surveyor had occasion to report that 4 inches in depth of rain had fallen in one hour on the first of that month, — a circumstance that cannot be too extensively known at a time when much sewer work is likely to be executed in this country; for, having once experienced such a fall of rain, it is right to expect and provide for the like occurrence in future."

Mr. J. Newton says, "On the 29th of July, 1857, he registered at Preston $\frac{3}{4}$ of an inch of rain in thirty-five minutes; and on the 8th of October, 1861, nearly the same depth in thirty minutes."

The Croton Aqueduct Board speak of a storm in 1866 as

follows: "The use of the pipe sewers has proved entirely successful; and, thus far, no complaints have reached the department of any stoppage or inefficiency in their working. No severer test of their capacity could be required than the effects of the extraordinary rainfall of Oct. 30–31 last, in which, in a period of about five hours, upward of 4 inches of rain fell."

It is probable that there is never any rainfall which entirely reaches the sewers. Especially in the summer season, when the most rapid rainfalls occur, there is much loss by absorption and evaporation.

In a report of Mr. Bidder, Mr. Hawksley, and Mr. Bazalgette, distinguished English engineers, made in 1858, on the subject of the metropolitan drainage, it is stated that observations had been made which had enabled them to arrive at some reliable conclusions, and that

"The result of these observations distinctly establishes the fact, that the quantity of rain which flowed off by the sewers was, in all cases, much less than the quantity which fell on the ground; and although the variations of atmospheric phenomena are far too great to allow any philosophical proportions to be established between the rainfall and the sewer-flow, yet we feel warranted in concluding, as a rule of averages, that $\frac{1}{4}$ of an inch of rainfall will not contribute more than $\frac{1}{8}$ of an inch to the sewers, nor a fall of $\frac{4}{10}$ of an inch more than $\frac{1}{4}$ of an inch. Indeed, we have recently observed rainfalls of very sensible amounts failing to contribute any distinguishable quantity to the sewers."

Mr. W. Haywood said, in a discussion before the Institution of Civil Engineers in London in 1865, —

"The observations of Mr. Bidder and Mr. Hawksley in 1857, upon the Savoy-street sewer, showed, that, of a rainfall of 2.90 inches in twenty-six hours, only 64½ per cent of the fall was delivered into the sewers, all the rest being either absorbed or evaporated. In the Ratcliff highway sewer they found, on the same occasion (which was an unusual rainfall, it having rained without ceasing, he be-

lieved, for twenty-six hours), that 52 per cent of the total quantity only was discharged into the sewers. It so happened, that, without any co-operation with the gentlemen named, he was, at the same time, engaged in gauging the flow of the London-Bridge sewer, which drained an area of 2,250 acres, partly urban, and partly suburban: it was necessary that this should be known, as the character of the surface much affected the quantity delivered into sewers in times of storm. Now, with the same rainfall, or rather a fall of 2.75 inches instead of 2.90 inches, being the amount recorded by Mr. Glaisher on the occasion alluded to, he found, that, in the London-Bridge sewer, 53 per cent of the total quantity only ran off.

"On one occasion, in April, 1858, he had gaugings taken of the same sewer, when 0.24 of an inch of rain fell in an hour and a half. He then found that 74 per cent of the total quantity was run off, leaving 26 per cent absorbed or evaporated. Of a rainstorm of 0.54 of an inch in five hours, in June, 1858, there was delivered into the Irongate sewer, which drained an area entirely paved and built over, as much as 94½ per cent of the total rainfall; and that, of all the storm-gaugings he had made, was the greatest percentage of rainfall he ever knew to be discharged by a sewer. In August, 1858, with a rainfall of 0.48 inch in one hour and two-thirds of an hour, he found only 78 per cent of the total quantity discharged into the Irongate sewer. There were, of course, many circumstances which would affect the quantity of water which would be discharged into sewers from rainfalls: no two cases would be alike. Storm-gaugings had been, he believed, but little taken by any one: in fact, it was a difficult matter to get them taken at any time, as they required men to be in readiness at any moment to make the observations, and competent assistants to see that the men did their duty. He had paid much attention to these points for many years: he had had the requisite staff in readiness; and he believed his observations were as accurate as it was possible to make them."

Mr. Baldwin Latham, C.E., of London, says, "In the case of Croydon, where the geological formation principally consists of gravel overlying chalk, the amount of rain contributed by a storm of 0.72 of an inch in twelve hours, in October, 1865, did not yield more than one-tenth of it to the sewers."

The experience of Mr. Hawksley has been very great; and his formula for the dimensions of sewers is used by English engineers of the highest standing. He stated to the Institution of Civil Engineers, in 1852, that "the most serious inconvenience had not always been found to arise from a sudden and heavy fall of rain of short duration, but more frequently from a prolonged fall of less hourly amount."

Not only are smaller sewers sufficient to carry a given rainfall by reason of the loss by absorption, evaporation, and other causes, but also on account of the length of time required for the water to reach the sewers. That which falls near the outlet runs through the sewer, and escapes, before that falling at a distance has reached it.

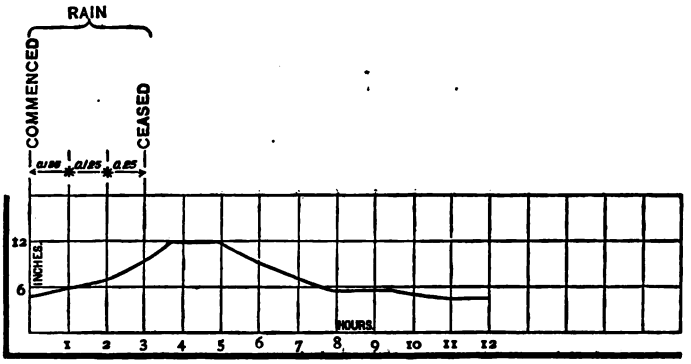
Mr. John Roe had an experience of twenty years as surveyor to the Holborn and Finsbury districts, during which time he took repeated observations of the effect of storms in filling the sewers, requiring for their record more than a hundred memorandum-books. Rain-gauges were kept to ascertain the depth of rainfall. The observations seem to have been made at frequent intervals, and through day and night when necessary.

To illustrate the length of time required for the water of a rainfall to reach the sewers, Mr. Roe gave two illustrations, which were published in the Report of the General Board of Health, London, in 1852. From those illustrations the cuts given on the following page were copied.

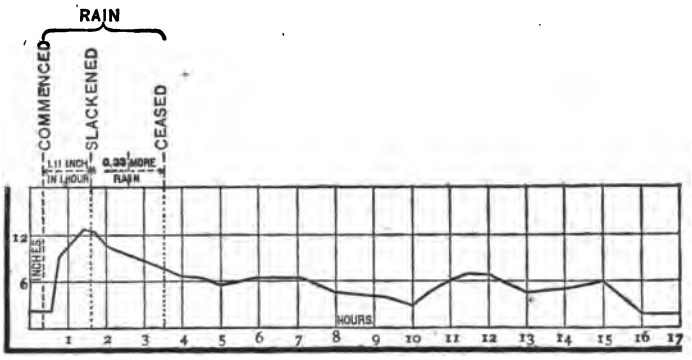
Unfortunately, Mr. Roe does not give the rate of inclination nor the character of the surface from which the water flowed, nor other facts which it would be useful to know; but I infer that the diagrams are given as fair samples of what may be expected in a district like his, where the

extreme difference of elevation is about 400 feet in a distance of five miles.

In the first case, half an inch of rain fell in three hours; and, at the end of twelve hours, the effect of the storm had ceased in the sewer.



No. 1.



No. 2.

In the second case, 1.11 inch of rain fell in one hour, followed by 0.33 inch in the next two hours; and the effect ceased in about sixteen hours.

We estimate from the diagram, in the first case, that, if the total effect had been expended at the maximum rate of flow, all the storm-waters would have been discharged in four and a half hours; and from the middle of the storm to the mid-

dle of such maximum flow would have been about three and nine-tenths hours. The maximum rate of flow actually continued about two hours after the storm had ceased.

In the second case, we estimate, that, at the maximum rate of flow, the storm-waters would have been discharged in six hours. At a uniform rate of rainfall, taking the first hour as a basis, the storm would have lasted about an hour and eighteen minutes. In this case, the maximum rate of flow occurred at about the time the storm slackened; but from the middle of the storm to the middle of our estimated maximum flow would have been about five and seven-tenths hours.

In a letter dated Dec. 3, 1852, written in defence of his tables of sizes of sewers for carrying off one inch of rain per hour, based on his observations, and under circumstances which would induce him to give the heaviest drainage with which he was acquainted (his sizes having been thought too large), Mr. Roe said, "I have observed 25 cube feet of water per minute per acre reach the sewers from an inch fall of rain in the hour, from a surface where the houses have much garden-ground attached; and in another case, where the houses were nearer together, 33 cube feet per acre per minute. That greater falls of water do take place, and that not unfrequently, is a well-known fact. I have known ten instances of the kind during the period of my observations in the Holborn and Finsbury sewers" [twenty years].

The total quantity of water from an inch of rain in an hour would amount to 60½ cubic feet per minute per acre.

The sizes of sewers in Providence have been based on the supposition that 30¼ cubic feet per minute per acre would need to be carried away in the sewers without entirely filling their section. The formula by which the sizes are determined gives rather larger sewers for given conditions than would result from Mr. Kirkwood's formula proposed for Brooklyn, and larger than would result from Mr. Hawksley's formula — so generally used by English engineers — on

low grades and large sizes, but smaller for great falls and small sizes, and larger in all cases than the tables of sizes given by Mr. Roe.

On the other hand, the sizes are smaller than would be required by the formula of Neville, except for the smallest sewers.

I have used this formula as a guide in determining the sizes of sewers for many years; and the practical results have encouraged me to feel very safe in continuing to do so.

No formula can be used arbitrarily for all cases: the local circumstances must vary the results, according to the judgment of the engineer.

Recently I have made a modification for the purpose of giving expression to the allowance for slope of the surface on which the rain falls, which has heretofore been made a matter of judgment in each case.

The first sewer constructed in Providence, under this department, was in North Main Street. The grade of the sewer for about nine-tenths its length — 2,558 feet — is 0.28 per 100. The general slope of the surface from North Main Street to Prospect Street rises at about twelve to fifteen feet per hundred. The mean of grades on ten streets between North Main Street and Benefit Street is 13.35 per 100; on seven streets between Benefit Street and Congdon Street is 14.47 per 100; on eight streets between Congdon Street and Prospect Street is 7.53 per 100. Bowen Street, between Congdon and Benefit, falls 24.40 per 100 to Wheaton Street, and 17.86 per 100 to Benefit Street.

This is a much steeper urban territory than I had previously had experience with; and I have since thought that possibly too little allowance was made for the slope in determining the size of the main sewer. But no case of flooding in the public sewer has come to my knowledge, though we have had several very heavy rains since its construction in 1871.

At the present time, a considerable territory, which it is proposed to finally turn through the College-street outlet, discharges its waters through this sewer.

I observed the effect of a very heavy rain, on the afternoon of the 22d of last August, upon the flow of the North Main Street sewer. An unusually large proportion of the rainfall probably reached the sewer, as the ground was thoroughly soaked, and the surfaces of buildings and streets had been well wet, and small cavities filled, by rains on the 20th and 21st, and by a rain of 0.85 inch depth, ending at about two o'clock on the 22d.

In "The Providence Daily Journal" of Aug. 20 appeared the following: —

> RAIN. — On Thursday the 14th we had one inch and nine-tenths (1.90); yesterday and last night we had one inch and twelve-hundredths (1.12); making, in less than a week, a rainfall of a little over three inches (3.02). The ground in this vicinity is thoroughly wet. If we have a severe drought, it must be late in the season. A. C.
>
> AUG. 19.

Dr. Caswell's records show a fall of 3.90 inches on the 22d in five hours.

Our records, carefully kept at Hope Reservoir, — within the North Main Street district, — show a fall of 4.06 inches from the 14th to the 21st inclusive, of which 0.30 fell on the 21st. The total rain on the 22d was 4.02 inches, of which 0.85 inch fell before two o'clock. At about three o'clock, P.M., the rain began again; and in three hours 2.77 inches of rain fell. During a part of this time, the rain was considerably heavier than the average. While and after the fall was heaviest, I spent nearly an hour examining the sewer. At the outlet, under Great Bridge, the sewer was running about or slightly more than half full; between Market Square and Meeting Street the sewer was from one-half to two-thirds full, though, in one or two places, occasional waves carried the water a little higher; at Smith Street, where the men had been removing gravel and stones which had been washed in, during a storm, through a lateral sewer at that time being laid, and where a portion of the cleansing apparatus still hung in the manhole and dipped into the flow of the sewer, the run of water was

so high, that the wavy motion just carried the surface of the water to the crown of the sewer. It thus appears that the rain which many inhabitants thought was among the heaviest they ever knew, was well taken care of; but, as the sewerage of the upper portion of the district approaches completion, it may become desirable to construct through Smith Street into Moshassuck River such an overflow for excessive storm-waters as has been contemplated for some of the other sewers. Especially is this true if the frequency of heavy storms, so notably increased in the last few years, is to continue.

Perhaps I have given an unnecessary amount of space to the question of rainfall: but it is one of great importance to my mind, involving, on the one hand, expense from damage to property if the sewers are too small; and, on the other, expense of construction, and loss of scouring effect in the ordinary flow, if the sewers are needlessly large.

DEPTH OF SEWERS.

The depth at which the new sewers have been laid has excited considerable discussion, of which the tendency has been against such a depth as is believed, on the whole, to be for the best interest of the community.

It is not thought best, as a rule, to place the bottom of the outlets, at the established harbor-line, lower than about one foot above mean low tide. The Dorrance-street sewer, which is circular, five feet and a half in diameter, and running through the lowest section of the city, is planned so that the bottom of the invert, when extended to the harbor-line, will be at mean low tide. Even at that level, and with the least inclination considered allowable (one foot in a thousand), the material of the crown of the sewer will form the surface of the street at the junction of Washington and Cove Streets. As the rise and fall of the tide is five feet, the inside crown of the sewer will be half a foot above mean high tide at the outlet.

This limit of height on account of the tide compels a less depth for the sewers, in many cases, than would otherwise be desirable.

Mr. Kirkwood, in his description of the Sewerage Works of Brooklyn, says, "The rise and fall of the tides average five feet. The bottom of the outlet of the sewer is generally placed about a foot above low-water mark."

Mr. Chesbrough, in his Report on a Sewerage System for New Haven, says, "The bottom of the main sewers at the outlets is to be about one foot above low tide, the East-street outlet having been constructed a little higher. Experience shows that sewers which are not unnecessarily large, and have proper inclination, very rarely have deposits in them where the tide ebbs and flows through them." "It may be proper to state, that the outlet sewers so located would be empty twice in twenty-four hours, and that the scouring effect of this discharge would have the tendency to prevent the deposit of sediment in the sewers."

The experience we have had where the sewers have been completely constructed indicates that the action of the tide is a positive advantage, — the sewers keeping quite clean, except about where the level of high tide intersects the bottom of the sewer; and it seems probable that the flow of sewage, when the houses are generally connected, will tend to prevent settlement at that point.

Our general rule has been, where practicable, to place the inside crown eight and a half feet below the level of the curbstone. The irregularities of the surface, and the necessary inclination of the sewer, cause this depth to be sometimes less, and sometimes greater, than the standard. In the steep hillside streets, especially where rock is encountered, the grade has usually been raised to seven feet below the curb.

On Plate 13 a section is given to show the greatest allowable depth of a private drain, according to the rules established by the Board of Aldermen, when the main sewer is eight and a half feet below the curbstone. On a street forty

feet wide, the top of the private drain, at the line of property, cannot be more than eight feet and an inch below the curb; and, at a distance of a hundred feet from the street, the depth cannot be more than six feet. On a wider street these depths must be less. If, however, the grade of the street is steep, and the junction is carried well below the property to be drained, the depth of the private drain in the property can be increased.

On business-streets, a greater depth than the above would, in many cases, be very valuable.

One of the greatest advantages of a good system of sewerage is the withdrawal of subsoil waters below the foundations of buildings. This has been proved, very generally, to increase the health of communities, especially in lessening the amount of consumption and other lung-troubles. Of course, the greater the depth of main sewer, the more marked is the effect produced.

Krepp, an English writer on "The Sewage Question," says the average depth of sewers is seldom much less than fifteen feet.

Baldwin Latham, author of "Sanitary Engineering," recently published in London, speaks of twenty-feet cuttings for sewers as ordinary.

A comparison of the cost of the large sewers built in the Holborn and Finsbury divisions with those in the Westminster division, made in Dempsey's "Treatise," gives the "average depth of excavation twenty feet." In giving the cost of sewers of medium size executed in the neighborhood of London, they are said to be "in an average excavation of fifteen feet." It is further shown that the regulations of the former commissioners of sewers for the city of London (perhaps still in force) required that the bottom of a common sewer should not in any part be less than twelve feet beneath the surface of the street.

"A sewer . . . passes under Canonbury (Islington) at a depth of sixty-eight feet from the surface."

Mr. Haywood, engineer to the city of London, has said,

"The sewers I have built are rarely less than from twelve to fifteen feet below the surface to the water-bed."

The least general depth for the main sewers in Leicester is twelve feet below the surface.

By the Health Report of 1854, it appears, that, in Rugby, "the average depth of the public sewers is ten feet six inches, and two main lines are, in parts, one twenty-one, and the other twenty-eight feet deep." It had been claimed that these sewers are too shallow for a densely-populated district.

Corfield (1871), after speaking of the evils of the too shallow depth of sewers, says, "The new sewers in most of the towns have been placed at such depths as 'from sixteen feet in the mid town to four or five feet in many other parts of the town (Stratford-on-Avon).' At Rugby they are 'at an average of eleven feet deep from the surface, varying from seven to twenty-five feet.' At Worthing they begin superficially, and are twenty feet deep at the outfall. The London sewers vary much in depth."

He says, further, that the sewers of Penzance — from which surface-waters are excluded, and with no subsoil drains — "lie at an average depth of nine feet."

In the Minutes of Proceedings of the Institution of Civil Engineers, it appears that in Manchester, Eng., "the main or street drains are laid at various depths, from 9 feet to 30 feet." Also that in Dundee "the average depth of the sewers is 12 feet, which was considered necessary in order to secure proper drainage of the cellars. The surface-levels being very irregular in many places, the depths of the cuttings consequently varied; the smallest depth, which was in trap-rock, being 7 feet, and the greatest 21 feet. The deepest cutting in trap-rock (19 feet) occurred in the centre of the town, across the base of Castle Rock. The total amount of rock excavated was 24,000 cubic yards." Also in a report on the sewerage of Newport, that "the prices of the sewers up to and including 3 feet by 2 feet 2 inches are given for an average depth of 10 feet, for the pur-

pose of easy comparison, though many of them were laid deeper. The depths of the sewers 4 feet 6 inches in height are the average of excavations actually made, the greatest depth being about 20 feet." The depths given were 12½, 13½, and 15½ feet. A statement in regard to the sewers of Paris in 1865 gives the depth for one class of sewers at about 10½ feet, and for another class about 14 feet.

From a plan representing the drainage of the new portion of Hamburg, I find forty-eight points where a comparison of grades can be made, showing the depths to be from 11 to 19.5 feet. The Hamburg foot is about 0.94 of an English foot. The average depth of the forty-eight cases is about 13.3 English feet. At one point where a sewer was tunnelled, it is 40 feet below the surface.

Much of this territory was originally marsh-land, and subject to overflow.

Col. Adams's Report to the Commissioners of Drainage of the City of Brooklyn, in 1857, contains the following statement: "The grade of street-sewers generally to be 13 feet below the level of the curb. Custom, both here and in the city of New York, may be considered as having fixed this dimension." The present practice in Brooklyn is to lay the "brick sewer invert 13 feet, pipe sewer invert 12 feet, below grade of street."

In Boston, it is the practice to "lay suburban sewers at 9 feet, except when there is great disparity in the different sides of the street, and then somewhat deeper; or in ledge, perhaps, skim down to 7½ or 8." For business, a depth of 12 feet is considered about right; "that is, give 10 feet clear to the highest water-line in the sewers."

In Jersey City, the chief engineer has "made it a rule, where possible, to arrange the water-run of sewers 12 feet below curb-grade."

In Newark, N.J., "the sewers generally are about 13 feet below the street-grades; that depth being considered sufficient for ordinary cellars. Some of the sewers are much deeper, and many on the low ground are of less depth; but, wherever practicable, the depth above named is aimed at."

In Philadelphia, the chief engineer makes "the house connection with sewers in the centre of a 60-foot street at 8½ feet below curb-level, which gives sufficient fall from the average depth of cellars; and, if practicable, make the bottom of the connection at springing-line of sewer, which would make the bottom of a 3-foot sewer 10 feet below curb-level."

The city civil engineer of Cleveland writes, "We cannot adopt any uniform depth for sewers in this city, the surface of the ground is so rolling; but, for main sewers, our minimum depth is 20 feet, and for branch sewers 12 feet, unless it be in exceptional cases."

The acting chief sewerage engineer of Cincinnati writes, "We generally put our brick or main sewers to the depth of 15 feet, and our pipe or lateral sewers to the depth of 13 feet."

Mr. Chesbrough, in his Report to the City of New Haven, says, "Generally the bottom of the pipe sewers should be 10 feet below the grade of the street; and the bottom of the brick sewers should be about 2 feet lower, or 12 feet below the grade of the street."

I had a special wish to know the ruling depth in Chicago, on account of the great expense incurred to raise the grades in that city to secure proper drainage. I therefore wrote to Mr. Chesbrough, who replied as follows: —

OFFICE OF THE BOARD OF PUBLIC WORKS,
CITY HALL, CHICAGO, Jan. 7, 1874.

J. HERBERT SHEDD, Esq., *Chief Engineer Water-Works*,
PROVIDENCE, R.I.

DEAR SIR, — I have never been able to fix, in my own mind, upon a depth for the bottoms of the inverts of sewers below the surfaces of the streets above them to suit all or even the generality of cases. My opinion is, that it is best to take 12 feet where you can get it; and sometimes it is very important to have even more. In Chicago we rarely have as much as 12 feet, and often have to get along

with 9 feet, and even less, especially where the streets have not been brought up to grade yet, and may not be for years to come.

Yours very respectfully,

E. S. CHESBROUGH.

Subsequently Mr. Chesbrough wrote, —

"We endeavor here to look ahead, and make some difference, on account of expense, between the depths of sewers on streets likely to become important business-thoroughfares and those likely to be used only for private houses."

The following is a copy of a letter received from St. Louis: —

CITY OF ST. LOUIS, ENGINEER'S DEPARTMENT,
ST. LOUIS, Dec. 23, 1873.

J. HERBERT SHEDD, *Chief Engineer Providence Water-Works.*

DEAR SIR, — Yours of the 18th instant is at hand, inquiring about the average depth of our sewers; and I would say that our main sewers vary from 10 to 60 feet in depth, as the topography of our city is such that it is necessary to pass through dividing ridges to reach basins which originally drained through cavities in the rock which underlies the place. Some of these basins cover areas of upwards of 1,000 acres, one of which has just been reached by a tunnel through the solid rock, 1,400 feet long, the deepest point being 60 feet below the surface of the street; another by a sewer made in open cut 47 feet deep; and there are several others similar to those mentioned.

The bottom of Mill-creek sewer, which is 20 feet wide and 15 feet high, is from 20 to 34 feet below the surface. This sewer has now reached a distance of $2\frac{2}{8}$ miles from the river.

But for the smaller sewers, where they follow a regular inclination, the average depth is about 16 feet. This is for public sewers which are constructed for main channels of drainage, to receive district sewers, which are carried in all

directions to drain the district, — these are made at an average depth of about 12 feet.

The sewers first made in the central part of the city, about twenty years ago, are from 10 to 12 feet deep from the surface to the bottom of the sewer, which answered for a while: but improvements with sub-cellars have, of late years, demanded deeper sewers; and some have been made by private enterprise for special purposes. But I find that a depth of 16 feet for main sewers in the street, and 12 feet for district sewers, which are generally located on alleys, will give general satisfaction.

If you should desire any further information on this subject, I would cheerfully give any at my command.

Very respectfully,

WM. WISE,

General Superintendent of Sewers.

It will be noticed that sewers are very rarely laid as shallow as they have been in this city. I have thought from the first, as I have repeatedly expressed to you, that perhaps we ought, wherever practicable, except on the steeper hill-side streets, to lay the sewers deeper than we have been doing. But public opinion has seemed, heretofore, to be decidedly against this. As the value of land increases, the need of deeper cellars will be felt more than it is at present; and the extent to which we ought now to provide for this need is worthy of serious consideration.

In comparing the depth of our sewers with the depth in other places, it must be borne in mind that we estimate the depth from the surface to the *crown of the sewer*. I have made this the rule, because it is of very little account where the bottom of a sewer is, when it is running full: we can have no drainage lower than its crown. Where sewers are made so large that storms never fill them, the crown-line is not a suitable guide; though, in such cases, deposits often accumulate to such a depth that the flow is carried to the crown.

MATERIALS FOR SEWERS.

The quantities of materials purchased by this department for the construction of the new public sewers have been about as follows: —

Bricks,	plain	2,727,391
	narrow wedge	763,266
	wide wedge	159,200
Pipe Inlets,	6 inch	2,296
	12 inch	268
	15 inch	24
Scotch Drain Pipe,	12 inch	24,815 feet.
	15 inch	2,850 "
	18 inch	192 "
	12″×6″ branches	5,953 "
	12″×12″ "	903 "
	12″×12″ double branches	3 pieces.
	12 inch quarter-turns	14 "
	15″×6″ branches	832 feet.
	15″×12″ "	126 "
	18″×6″ "	72 "
American Vitrified Stoneware Pipe,	6 inch	1,517 "
	12 inch	2,361 "
	15 inch	1,191 "
	6″ (short socket)	160 pieces.
	6″ double branches	192 "
	12″×6″ branches	765 feet.
	12″×12″ "	61 "
	15″×6″ "	140 "
Invert Blocks,	large	4,373 "
	small	1,887 "
Catch-Basin Coping and Gutter Stones,	513 sets, about one-third corner.	
Catch-Basin Covers		579= 45,061 pounds.
" " Traps		538= 35,600 "
Manhole Frames and Covers		650=219,881 "
Iron Sewer Connections		25= 3,114 "
Iron Rods for Manhole Ladders		214 pieces.
Outlet Stones		5 sets.

The above account does not include the bricks used in sixteen sewers, for which proposals were received previous to October, 1872. The estimated number of bricks used on those sewers, which were furnished by the contractors, is 1,003,000. The contractors have also furnished the flagging-stones for the bottoms of catch-basins, the cement and sand

for mortar, lumber and concrete for foundations, material for jambs, surfacing material, and all tools and labor, of whatever description, necessary to the full completion of the works.

Other materials than those used by us have been employed in other places for the construction of sewers. Some of these are less expensive in first cost; and it may be thought, on this account, that they should be used here: but it has been proved by experience, that, in order to secure permanency and durability of sewer-work, great care is required in the selection of proper materials, and that the best materials procurable are the cheapest in the end.

The interior surface should be smooth and uniform, to facilitate the flow of sewage, and to offer no foothold for rats, or crevices for admitting roots of trees. Common building-stone will not answer this requirement, unless plastered on the inside; in which case the mortar is liable to be destroyed by chemical and by mechanical action.

The chemical action of the sewage, and probably, in some measure, of the gases found in sewers, is often destructive to most kinds of cement or lime-mortar; sometimes eating away that of the joints in brick sewers, so as to compel extensive repairs or rebuilding. For this reason, our specifications require the narrowest joints that are found to be practicable.

The cement pipes heretofore made in this country, so far as I have had experience with them (which accords with the experience of many engineers), have failed to answer the requirements of public sewers; largely, I think, on account of such chemical action, though there are other causes tending to their failure. It seems probable, from experiments made with Portland cement, that pipes or concrete made from that material, with sufficient care, may be safely used for sewers, except in unusually trying locations.

The grinding action of sand and other solid matter flowing with water over the inverts of sewers wears them away more or less rapidly. To prevent such action as far as

possible, the hardest and toughest bricks should be used in that part of the sewer; and the pipes should be of a vitreous, imperishable material, tenacious, hard, homogeneous, and impervious in character, and uniformly glazed. Porous material is not suitable, nor pipes burned at a low temperature. Salt-glazing is more durable than the slip-glaze; and it has the advantage of requiring a more intense heat in the kiln, which insures a better pipe. Some kinds of clay which can be used to make sewer-pipes of a poor quality but fair appearance, if slip-glazed, are unable to stand the heat required for salt-glazing.

It will be noticed that three kinds of bricks are purchased. The plain bricks are of such shape as are ordinarily sold in the market, and are culled by us into several classes, according to quality, of which the best are used on the inside of the inverts, and the others in places of successively less importance; the poorest being built into the outer courses of manholes and catch-basins.

The wedge bricks are moulded through dies made after our designs, which give them shapes suitable for use in sewers of small diameter, and on inverts where the radius of curvature is small. The outer edge of the "narrow wedge" is half an inch wider than the inner edge; and of the "wide wedge" it is an inch wider. The inner and outer edges are curved to the proper radius. A small groove on each side of the "wide wedge" distinguishes it readily from the other. Bricks of this form allow less mortar to be used in the joints, and make more stable work in case the mortar is injured. The additional cost — about one dollar per thousand — is small when compared with the advantages gained.

The pipe-inlets are made to order, of stoneware, with one end cut on a bevel, so that, when the bevelled surface is placed true with the inside of a brick sewer, the axis of the pipe-inlet will make an angle of thirty degrees with the axis of the brick sewer. By this means the junctions of lateral sewers and drains are neatly made with the main sewers, so

that the current of the lateral shall join with that of the main with small disturbance to the flow. For an illustration, see Plate 5. The inlets are built in as the sewer progresses; and such as are not to be immediately used are plugged by plates of stoneware or by brick. The usual distance apart for inlets for house-drainage is twenty feet on each side of the sewer, or one inlet for each ten feet of sewer. At points where the main sewer is necessarily much deeper than is required for the drainage of cellars, vertical shafts of pipes are built up, and inlets are put in at the standard depth.

The prices of Scotch pipe and of American pipe suitable for our sewers have not heretofore been very different; and, as we have found the Scotch pipe to be of better and more uniform quality, we have used it almost exclusively. There are indications that the price of Scotch pipe will advance; and, on the other hand, the American manufacture has of late considerably improved. It is our wish, when it can be done without injury to the interests of the city, to use pipes of American make; and we watch with some care the progress of improvement.

The pipes are laid with full mortar joints, struck flush on the inside, and thoroughly cleaned out as the work progresses.

Invert blocks of two patterns, one for single-course and one for double-course sewers, have been made from our designs, for use in bad ground where an excess of water is very troublesome. A small section of each of these blocks may be seen on Plate 1; that for the single-course sewer on the $20'' \times 30''$ section, and that for the double-course on the section immediately under. The length of the blocks is about two feet. The continuous opening through the blocks forms a convenient land drain for getting rid of the subsoil water, which very much facilitates the construction of the sewer in many places, and also serves to protect the cement in the invert from running water while it is setting.

All the cement used on the sewer-works has been fur-

nished by the contractors, under a requirement in the specifications that it shall be the best American hydraulic cement, proved to be good by such tests as the engineer prescribes. Previous to May, 1873, the tests were such as the inspector or engineer could readily make on the ground, with the occasional breaking of a sample to test its tensile strength. It was found, on examination, that most of the mortar on the completed work was very hard and good; but in a few places it could be readily dug out with a soft-pointed stick, and some work was rebuilt in consequence. The greatest trouble, under such inspection, arose from the irregularity in the quality of the cement. Specimens from barrels in a lot generally good would not set at all under water; and others, exposed an hour in air, and forty-eight hours under water, had a tensile strength of only ten to fifteen pounds to a square inch.

We had tried cements from nearly all the makers, under various conditions of exposure, usually breaking the specimens after seven days' immersion in water. It was finally determined to mix the cement clear with as little water as practicable, and form it in a mould, giving convenient shapes at the ends of the specimens for clasping in the testing-scales, and a section of one square inch in the middle. These specimens were numbered, and the time of mixing recorded. After an exposure of half an hour in the air, they were immersed in water, remaining twenty-four hours; after which they were broken in the testing-scales, and their strength recorded.

In May we began testing every barrel of cement used, and branding those which were accepted. At first it was difficult to get enough cement to use that would stand a strain of 30 pounds. But the quality of that offered for sale by the principal dealers soon improved materially; though it is still found that some will not set in water, and some will not bear sufficient handling to get it into the testing-scales. About the first of August, the standard was raised to 40 pounds; then, in a week, to 45 pounds; and in another week

to 50 pounds, where it has been held ever since. Samples are often left immersed for seven days before breaking; but, for American cements, we find our usual test to give reliable results.

Specimens from 9,964 barrels of cement have been tested since the first of May: of this number 1,048 were rejected. The average strength of specimens from accepted barrels used in June was about 39 pounds; that from accepted barrels used in July was about 52 pounds; that from accepted barrels used after July, and previous to February, was about 63 pounds.

The strength of cement received at one time may average much greater than that received at another. At times, it is not uncommon for the strength to reach 90, and even 100 pounds. Many samples have borne a strain of 110 pounds per square inch before breaking. The average strength of five hundred samples each, taken from three different makers after July 1, was, respectively, 63.26, 64.40, and 65.45.

Since the plan of regular testing was adopted, the engineer in charge and the inspectors have constantly examined the cement joints in the brick-work, and they have been found uniformly good. In some cases where it was necessary to take down brick-work, they were obliged to break the bricks to get them out.

APPURTENANCES.

Facility for examination, cleansing, and repairs, is essential to a good system of sewerage. Manholes leading from the surface of the street to the sewer furnish the most complete arrangement for this purpose. They are placed at every change in the direction of the sewer, whether in line or in grade; so that, with a light in one manhole, a person at the next may see at once whether any obstruction exists between. The curves which form the junctions of lateral with main sewers furnish the only exceptions to this rule. Between points of change in the line of sewer, manholes are

placed, about one hundred feet apart on the smaller sewers, and at varying distances greater than this on the larger ones. Illustrations of manholes are given on Plates 6 and 7. Where the sewers are small, and the depths moderate, we have generally furnished steps for ascending and descending by projecting bricks on the sides, as seen in Plate 7. For larger and deeper sewers, the straight iron rods, about an inch in diameter, built into the manhole, as shown on Plate 6, are considered safer. The manhole frame and cover are illustrated on Plate 12.

The cleansing of sewers, either by flushing or mechanical appliances, is made very convenient by means of these manholes.

The covers of the manholes are perforated with holes, about half an inch in diameter, to allow an escape of sewer-air for the purpose of ventilation. The great number of these openings, and their position in the middle of the street, giving opportunity for diffusion, in a large proportion of surface-air, make this, on the whole, the simplest and safest mode of ventilation at present known. It is probable that it may be necessary, before a very long time, to make special provision for a much larger escape of sewer-gases than can safely be passed through manhole covers, at the ends of the sewers having a high elevation, especially from the lateral sewers on Prospect Hill.

Illustrations of catch-basins, and coping and gutter stones, are given on Plates 8, 9, and 10. They are placed on the sides or at the corners of streets, and usually receive a run of water from about two hundred and seventy-five feet of gutter, — rarely less than one hundred and fifty feet, or more than four hundred feet, except where the works are incomplete. In Europe, the catch-basins, or gullies, are generally placed about one hundred and twenty feet apart; and they are much smaller than those ordinarily used in this country. Ours are as small as it seems safe to make them in the present condition of the streets. Experience has proved that they may be filled with sand and gravel in a single storm.

The opening through the coping-stone is quite sufficient to take all the water that should pass through the basin into the sewer. If the heaviest storm of which I have undoubted information — 3 inches per hour — should fall on a street sixty feet wide, and no portion of it be evaporated or absorbed, and it should reach the opening without sensible velocity of approach, the opening would take all the flow from a length of six hundred feet of gutter, receiving the water from half the street. If the catch-basin ever fails to receive all the water it is intended to take, it will be because the gutter-paving is imperfect, and not because the opening is inadequate.

On the very steep streets, the velocity of water in the gutter, in a heavy rain, is so great, that it is difficult to arrange the paving to turn the flow into the basin. In such cases, some of the water passes by the opening; but it would be of no value to make the opening larger, though some more effectual arrangement for turning the water through it is desirable.

The chute, or connection between the catch-basin and sewer, is a twelve-inch circular pipe, and is as large as I have known to be used in any modern sewerage. A recent English author says the size of pipe for connecting street gullies with the public sewers, "in practice should not be less than six inches in diameter." The circular of the largest manufacturer of sewer material in England says the six-inch size is ordinarily used.

The floor of the catch-basin is formed of a single blue flagging-stone.

The trap is illustrated on Plate 11. It is made of cast iron, except the pin, which forms a hinge, that being of composition. After the plate is built into the brick-work, a bed of mortar is laid upon the side of the catch-basin, into which the trap is pressed, making a tight joint. The joint can be broken, and the trap lifted, at any time, if it becomes necessary to get convenient access to the chute.

Small round stones are filled around the catch-basins,

under the coping-stones, to a depth of four and a half feet, to prevent lifting of the coping-stones, or other injury, by frost.

The sewer-work has generally been done under contract, with the strictest inspection on behalf of the city. Notwithstanding the fact that the prices paid have been, as a rule, somewhat higher than are paid for the same sizes in some other cities, the contractors have, I think, in a majority of cases, done the work at a loss. This is probably owing, in large measure, to the very bad ground in which most of the sewers are built. The losses by the contractors have caused considerable increase in the rate of bids; and it has been thought best in several cases to do the work by the day. There are many advantages in this mode of doing the work; and it has proved, on the whole, more economical than to let the work at the higher bids. In the case of the Ives-street sewer, a saving of several thousand dollars was effected over the lowest bid received at the opening, though the ground proved rather worse than we anticipated.

PRIVATE DRAINS.

No amount of skill, care, and expense in building the public sewers will relieve the property-holder from the necessity of constructing his private drains with all possible care. These drains often cause, in the aggregate, more trouble, on account of imperfect plan and construction, than all the rest of a sewerage system.

The proper object of house-drains is to carry away from the premises all waste water, liquid refuse, and fecal matter; and, while arranged to perform this service effectually, they should also be so arranged that no sewer-gases can by any possibility be conveyed into houses. To do this, it is not enough to place water-traps at the various inlets of the house-drain, nor even to make the addition of a trap in the drain itself. The compression of the air in the drain, which may

often arise from many causes, will blow through any practicable traps at the inlets throughout the house; and the vacuum which has a tendency to form every time a large amount of water is thrown into the lower part of a house-drain makes a suction upon every trap that is above it. In this way the water is often drawn out of such traps; and, until they are again filled with water, a communication is opened for the passage of foul air into the rooms. Any imperfections at the joints of the drain will also allow such communication. There may be a dangerous amount of sewer-air in the house without its presence being suspected, as, in its worst forms, it is not necessarily of strong odor, nor in any way of a character to force itself on our attention. To prevent these evils, there should be systematic provision for constant ventilation in the drains, of such a character that the tendency would be rather for a draught from the house into the drains than from the drains into the house. The first requirement is to shut off, as far as possible, all communication for air from the public sewer to the house-drain; so that whatever the mismanagement of the sewers, either in construction or cleansing, the householder may be reasonably protected. For this purpose, our rules require all persons to place an effectual trap in the line of drain just before it leaves the premises. For an illustration of house drainage, see Plate 14. At the extreme left, the trap above referred to is represented: just back of it, connection is made with a down spout, which furnishes free communication for outer air to the drain, except when the spout is carrying rain-water. From the highest part of the soil-pipe within the premises a pipe of the full size is carried to a point above the roof of the building, making another open communication with the outer air. These two pipes, with the drain, form a siphon; and, under all ordinary circumstances, there will be a constant flow of air down the cooler leg, and up the warmer leg, keeping up a circulation of considerable value. Now, if the compression of air in the public sewer blows through the lower trap in the drain, the sewer-

air has a free escape to the outer air without causing an injurious pressure on the traps of the various inlets to the drain; and a sudden rush of water poured into the lower part of the drain is followed up by the outer air through one leg of the siphon, so that no vacuum can be formed sufficient to suck the water from the inlet traps. In the case of heavy rain, when the down spout is filled with water, no injury is done; but only a cessation occurs, for the time, of the flow of outer air through the siphon.

Private drains are often obstructed by carelessness, on the part of those using them, in admitting substances which they were not intended to receive. Sand, shavings, sticks, coal, bones, garbage, bottles, spoons, knives, forks, apples, potatoes, hay, shirts, towels, stockings, floor-cloths, broken crockery, &c., are among the substances that have been found in them.

Perhaps the most common and the most certain cause of obstruction to house-drains arises from grease, which, though fluid when it is hot, soon cools in the drains, and gradually, but certainly, closes them up. I have known drains from thirty to fifty feet in length closed nearly the whole distance from this cause. The amount which will collect from the waste of a single family is surprising to those who are not familiar with the subject. It ordinarily causes much more expense and inconvenience to allow this substance to run into the drain than to catch it in a grease-trap, from which it can be conveniently removed. An illustration of a trap for this purpose is given on Plate 15; and its proper position under a sink may be seen in Plate 14. The joint between the body and the cover may be well sealed by rolling up a rope of clay, about three-quarters of an inch in diameter, with a string through the middle, for convenience of handling, and laying it in the groove, when the cover will compress it so as to make a tight joint, that can be conveniently broken when necessary. I have sometimes had these grease-traps made with the top of the inlet-pipe level with the bottom of the outlet-pipe; in which case I suppose they will

bear longer neglect than when made as shown in this illustration. If such a thing is desired, the waste-pipe can be carried through the inlet, and dropped to the required level.

Vitrified and glazed stoneware pipes six inches in diameter are believed to be best for ordinary house-drains; lead or iron pipes four inches in diameter are suitable for soil-pipes; lead pipes two inches in diameter for sinks, if the distance to the grease-trap is short; and lead pipes one inch in diameter for bowls, bath-tubs, and other fixtures discharging comparatively clean water.

It is well to have one or more openings, covered with a cap, easily removable, at points in the drain, — as shown at the catch-basin on Plate 14, — so that a strong wire or flexible rod may be run into the drain to remove any obstruction that may occur. The use of a catch-basin in house-drainage is very rarely necessary, and should be avoided when practicable.

The established "Rules for laying Drains" are given in the Appendix. Persons are required to lay their private drains between the curbstone and the public sewer at the grade which will give the lowest allowable drainage to their estates, whether they wish to avail of such drainage immediately or not. The object of this is to prevent the tearing-up of the street-surface to relay the drains when such deep drainage becomes necessary.

The materials and workmanship for house-drainage should be of the best possible character. Care should be taken to provide against the ill effects of expansion and contraction, and against damage by settling of walls. The joints should be air and water tight: those in the stoneware pipes may be made of good cement-mortar; and, if a gasket is not used, great care should be taken to swab out the interior of the pipe, and leave all clean as the work progresses.

Although house-drains are laid at the expense of the owners of the premises to be drained, the "Rules" require the work to be done under the permission and supervision of the Water Commissioners, and under the immediate inspection

of their engineer of private drains; also that it shall be done by a licensed drain-layer, under bond to do faithful work. These restrictions have been proved by experience, in many cities, to be necessary to secure housekeepers from the great annoyance to which they would otherwise be frequently subjected from imperfect arrangement or unfaithful execution.

The experience in Chicago is thus expressed in a report by Mr. Chesbrough: "As the usefulness of the sewers depends so much upon the faithfulness with which house-drains are laid, past experience shows that this work ought never to be put into the hands of unfaithful or irresponsible persons. In some cases, not only individuals have suffered much annoyance, as well as loss, but the sewers have had to be cleansed at an otherwise needless expense. Probably no system better than licensing competent and faithful persons can be devised: but great caution should be used in granting the licenses; for the fact of unfaithfulness is not likely to be known, in many cases, till its consequences appear, which may not be for a year or two after the work is done, and the doer out of the city."

During construction, sand, gravel, and other materials, are likely to be washed into the sewers, and are sometimes carried long distances by the action of the water; even, at times, into other sewers previously constructed. These obstructions, if on contract-work, are removed at the expense of the contractor, who is responsible for the good condition of his work six months after completion.

In some cases, sewers, which could at present have no outlet except through old drains laid at a higher grade, have been ordered by the city government; and, where great necessity seemed to exist, they have been constructed. In these cases, wells or chimneys have been built at the lower end of the sewer, through which the flow must rise to find an outlet. Considerable attention is required to keep these sewers free from deposit; but no great trouble has

occurred except on the Transit-street sewer, at Brook Street. Here the lift is about six feet; and the lower end became, on account of an open joint caused by a displaced pipe, entirely stopped by sand and other material. The sewer was opened, cleaned, and in some parts relaid, at the contractor's expense. These sewers will soon have suitable outlets by the construction of other sewers, which have already been ordered; when the need of special attention will cease.

The works cannot, in the nature of things, be entirely free from defects, either in the plans or the execution.

No engineer or inspector is recommended for appointment, unless, after careful inquiry, he is believed to be strictly honest, and to have sufficient skill; and every person who has not proved himself well suited to his position has been removed.

If, as the work goes on, the best men are retained, and the others relieved, it may fairly be expected that the imperfections will be reduced to a minimum.

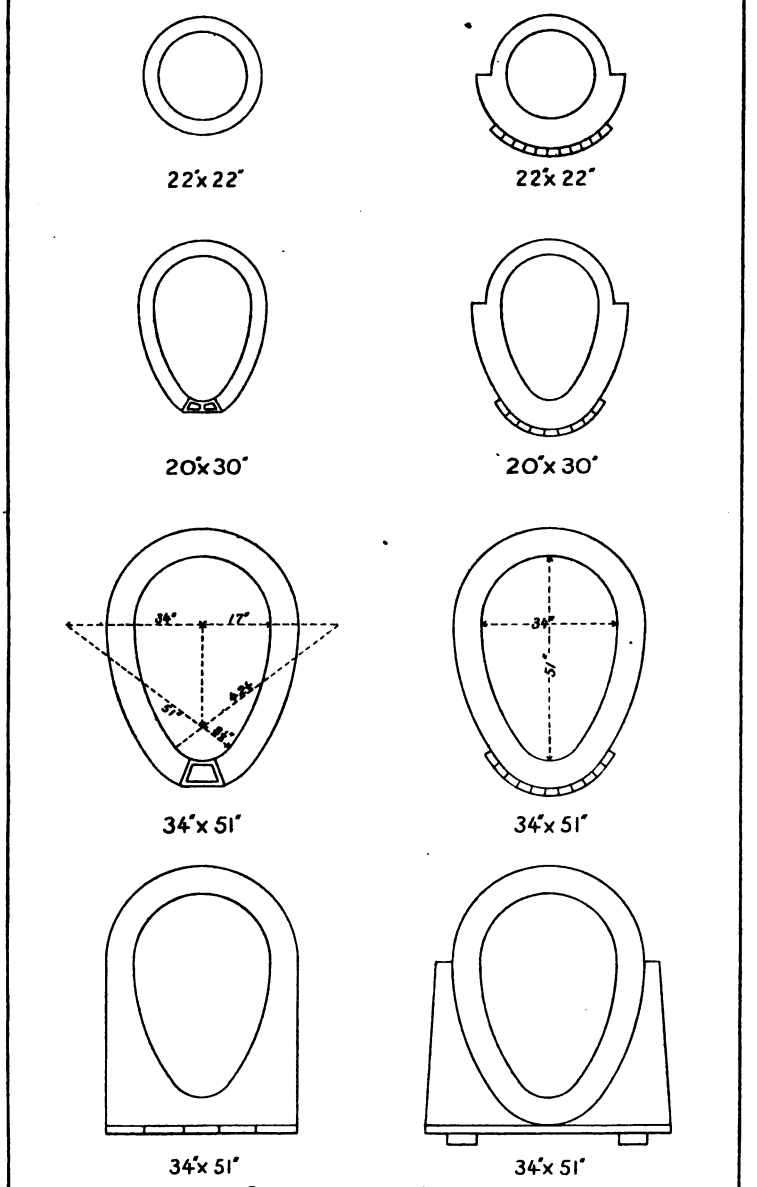
The work is, on the whole, better than I have ever before seen executed for a similar purpose.

I think the city is very fortunate in having a corps of men in the subordinate offices who have so skilfully and faithfully performed their duties.

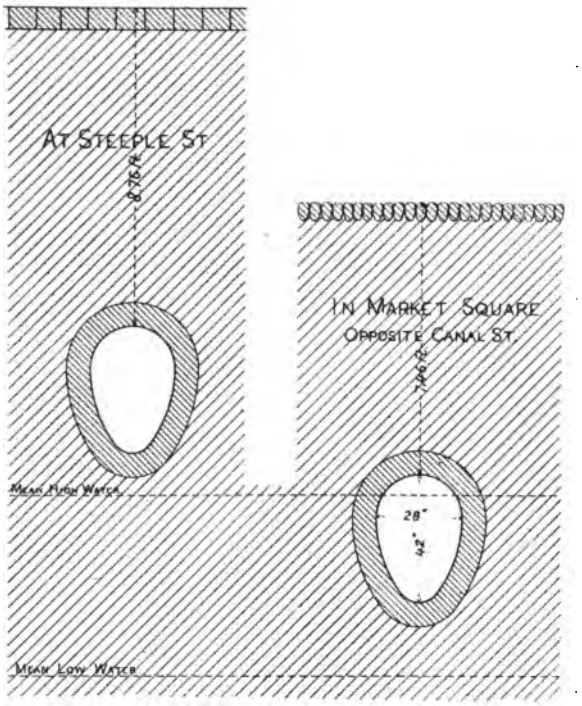
Respectfully submitted,

J. HERBERT SHEDD,
Chief Engineer.

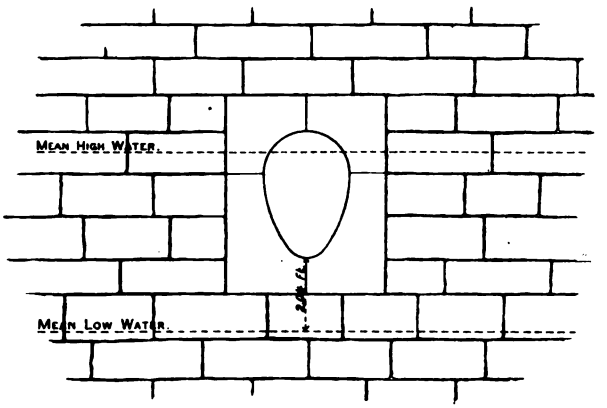
Plate 1.



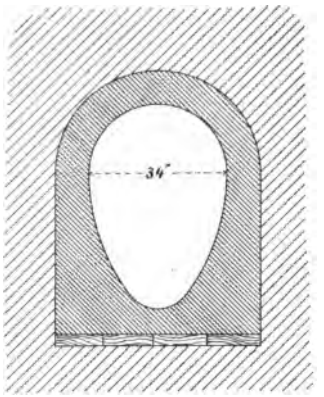
SECTIONS OF SEWERS.
Scale 1 in. = 4 ft.



Sections of North Main St. Sewer.

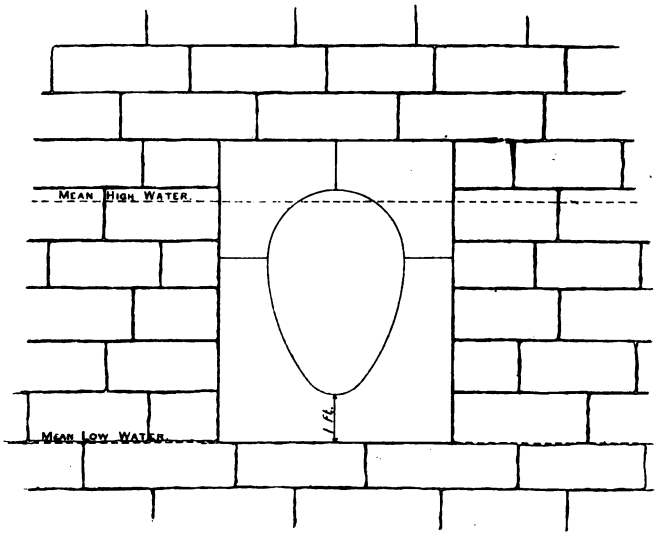


Outlet of North Main St. Sewer.
Scale $\frac{3}{16}$ in. = 1 ft.



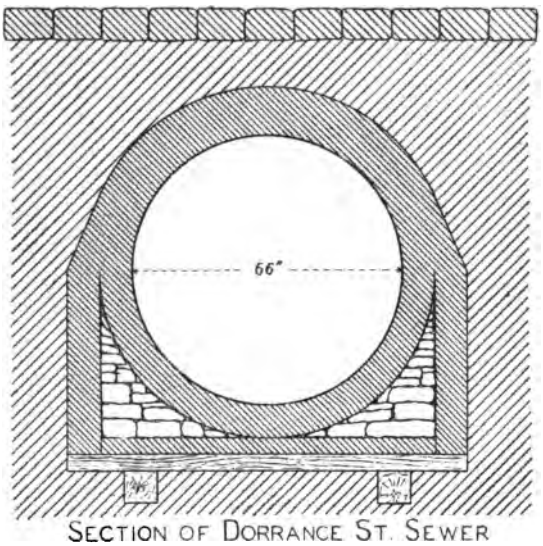
SECTION OF POINT ST. SEWER

NEAR THE OUTLET.

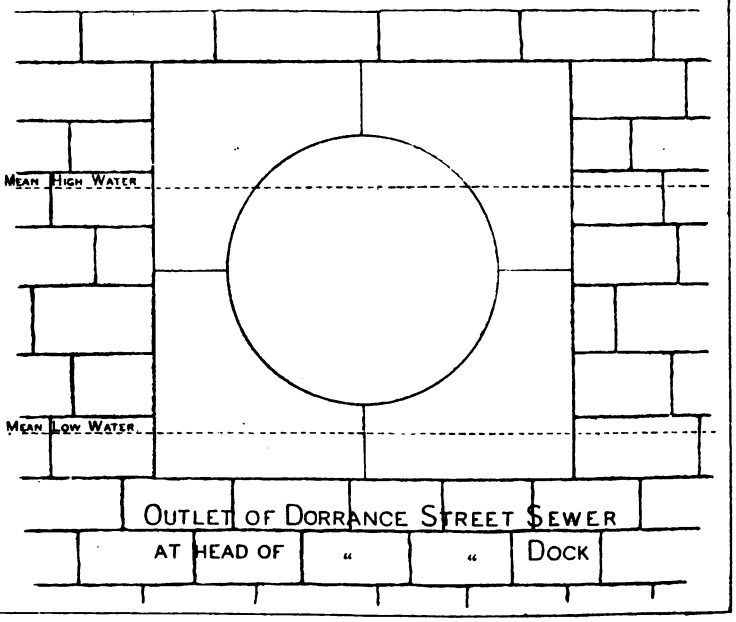


OUTLET OF POINT STREET SEWER.

Scale 1 in - 4 ft.

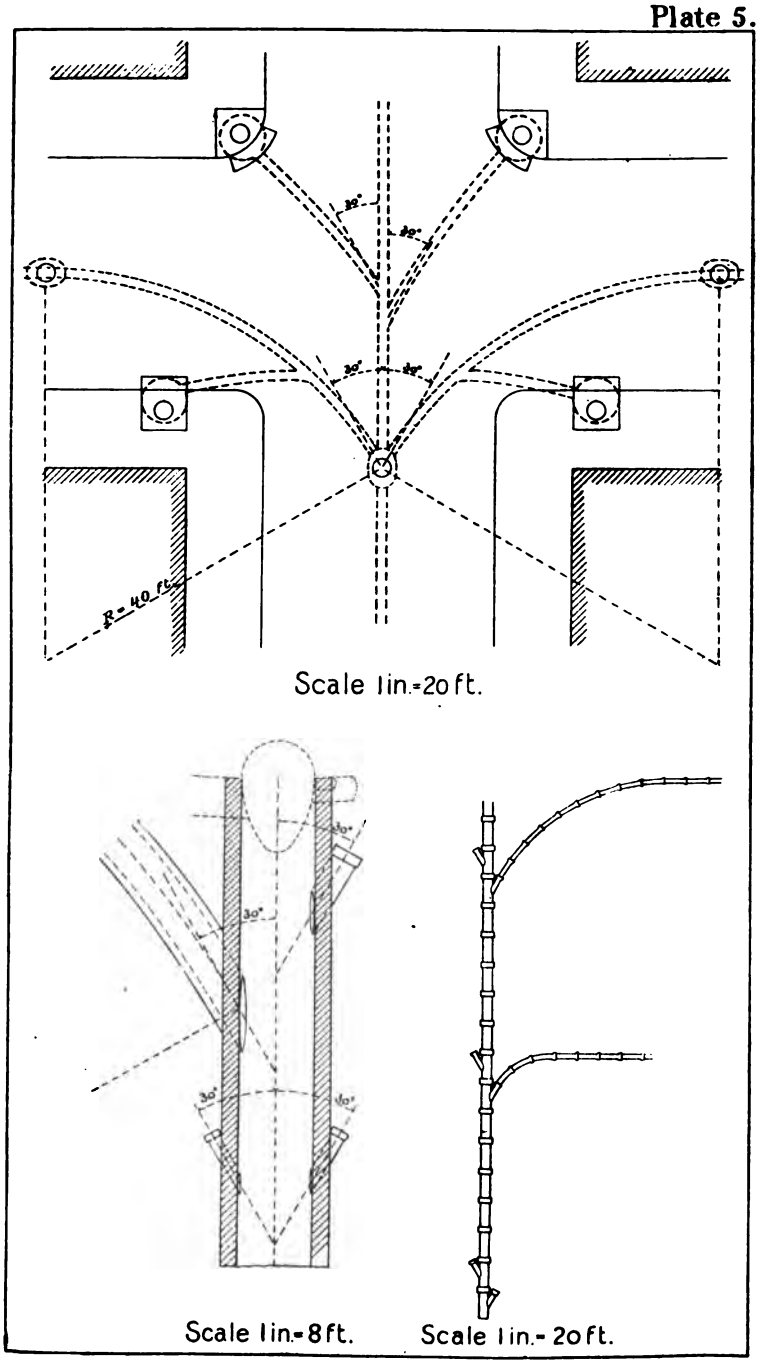


SECTION OF DORRANCE ST. SEWER
AT DYER STREET.
Scale 1 in.-4 ft.



OUTLET OF DORRANCE STREET SEWER
AT HEAD OF " " DOCK

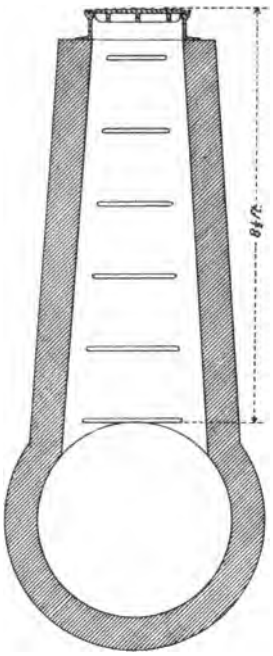
Plate 5.



Scale 1in.=20ft.

Scale 1in.=8ft.

Scale 1in.=20ft.



MANHOLE.
Scale 1 in - 4 ft.

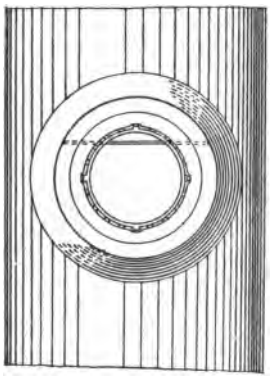
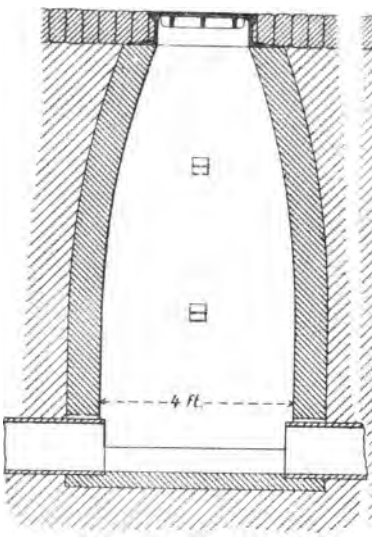
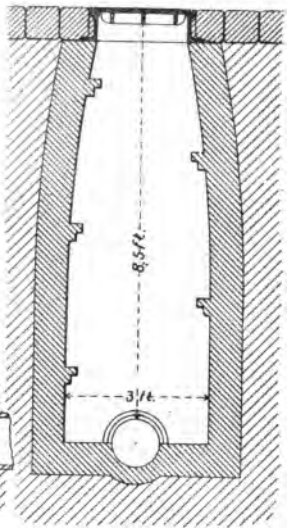


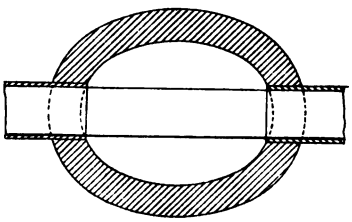
Plate 7.



SECTION.

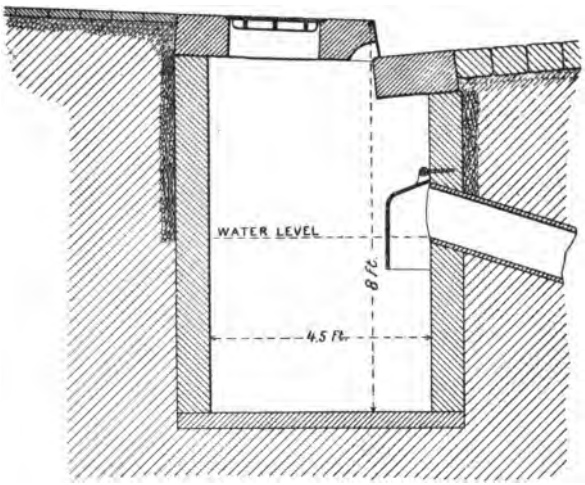


SECTION.

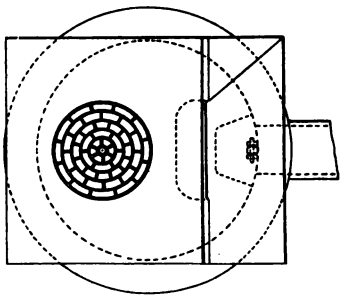


PLAN OF MANHOLE.

Scale 1in = 4ft.

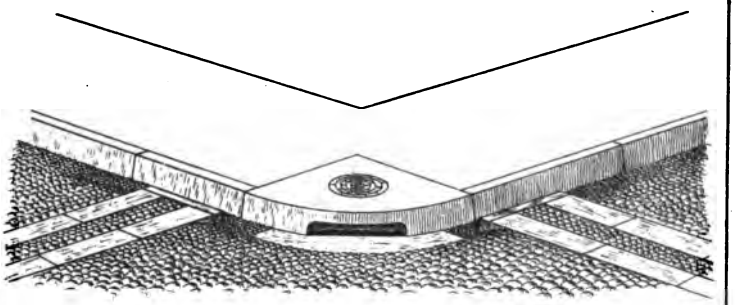


SECTION OF CATCH BASIN.

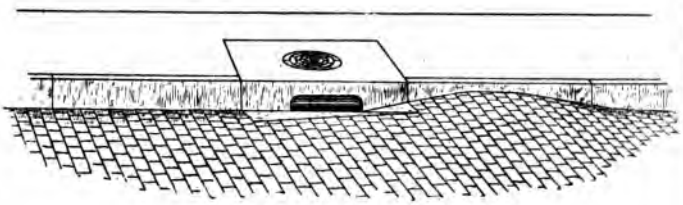


PLAN OF CATCH BASIN.

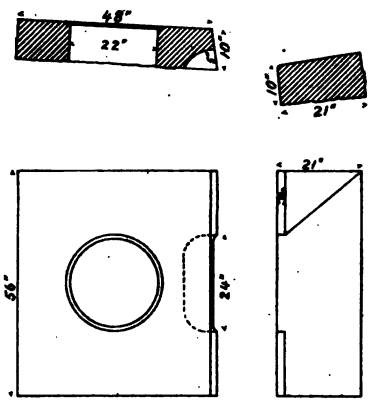
Scale 1 in. = 4 ft.



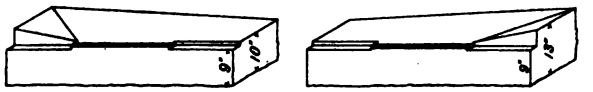
CORNER CATCH BASIN.



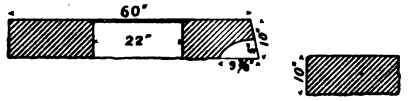
PLAIN CATCH BASIN.

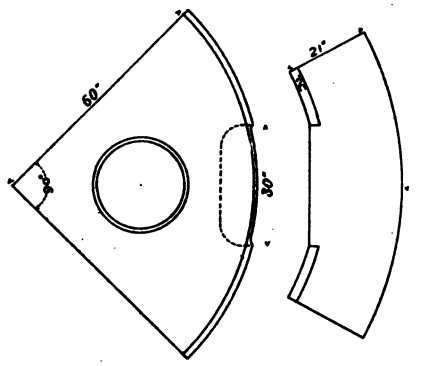


PLAIN COPING AND GUTTER STONES.

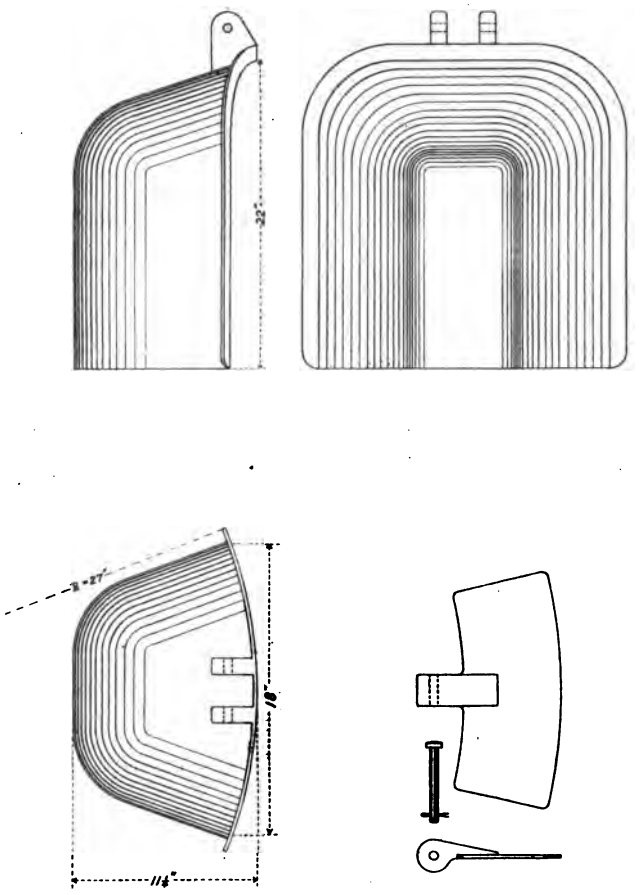


Right and Left Gutter stones.



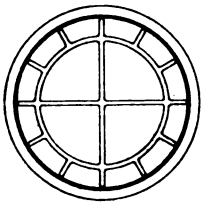


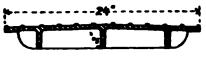
CORNER COPING AND GUTTER STONES.
Scale 1in=4ft.



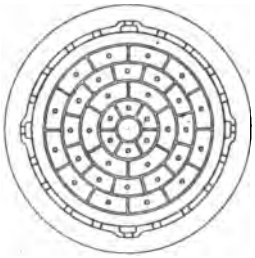
CATCH BASIN TRAP.

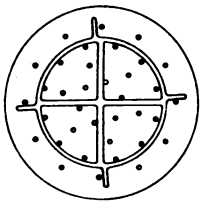
Scale 1 in = 1 ft.

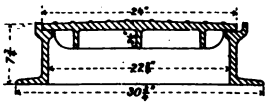




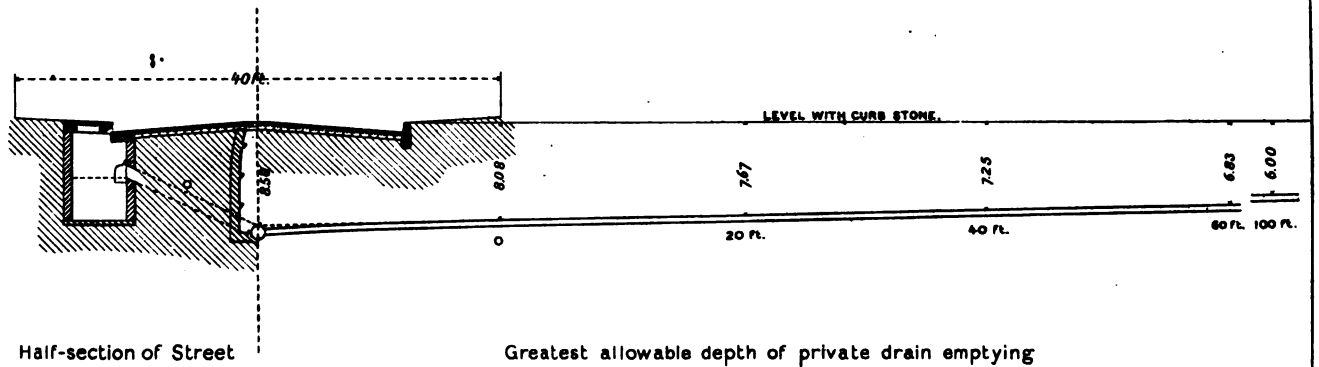
CATCH BASIN COVER.







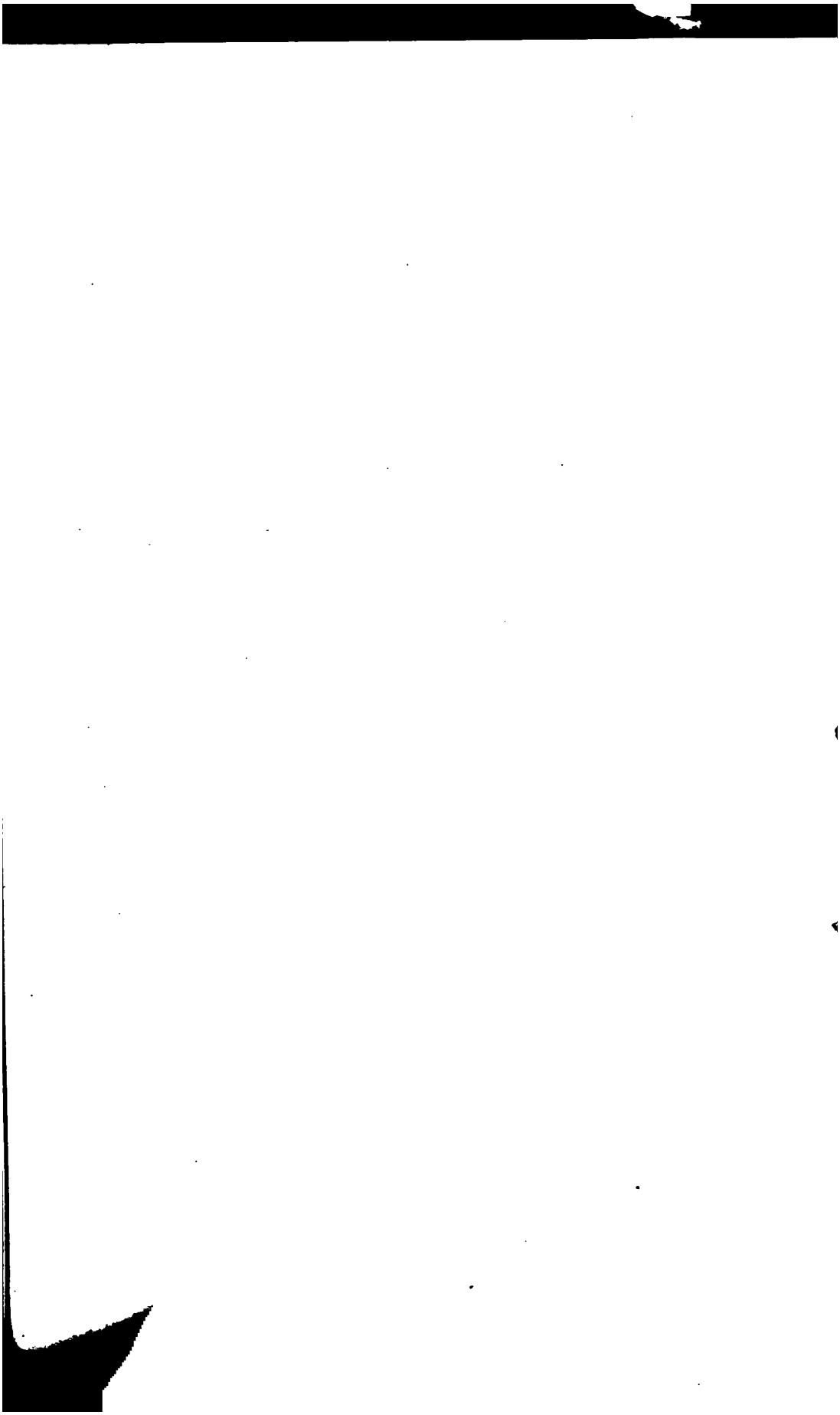
MANHOLE FRAME AND COVER.
Scale 1 in. = 2 ft.

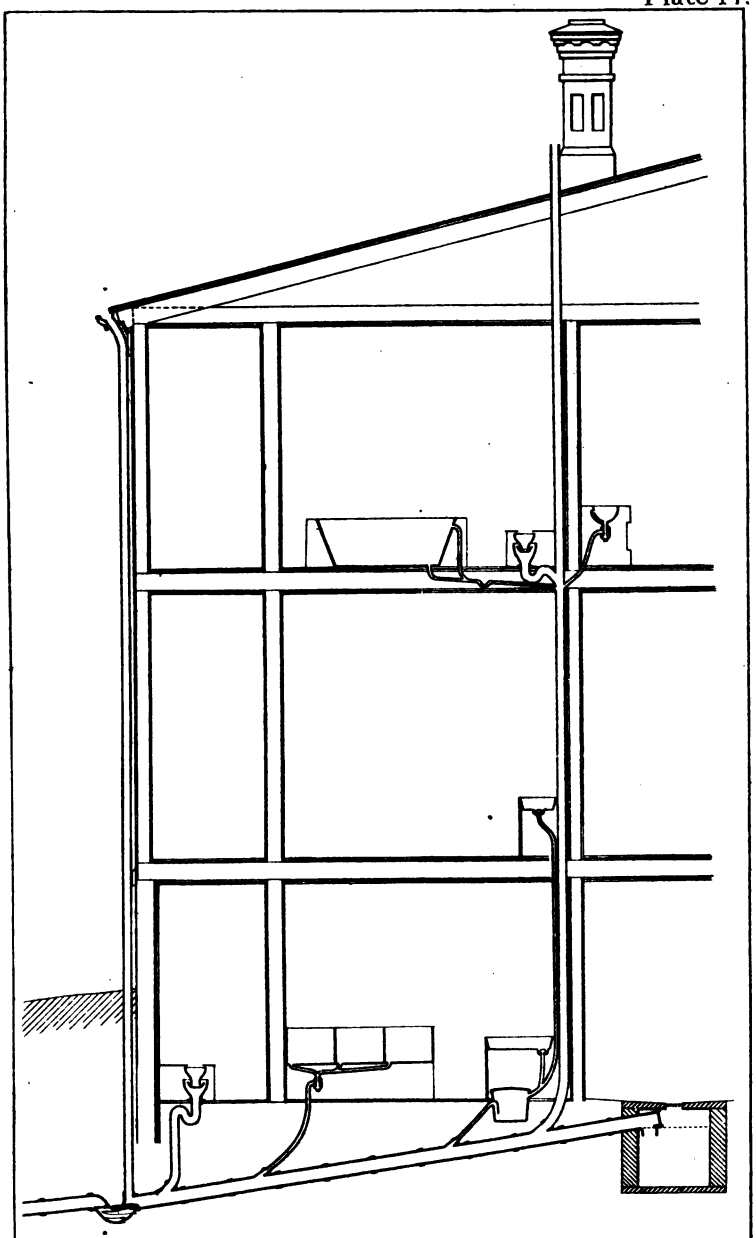


Half-section of Street showing Catch-Basin and Manhole.

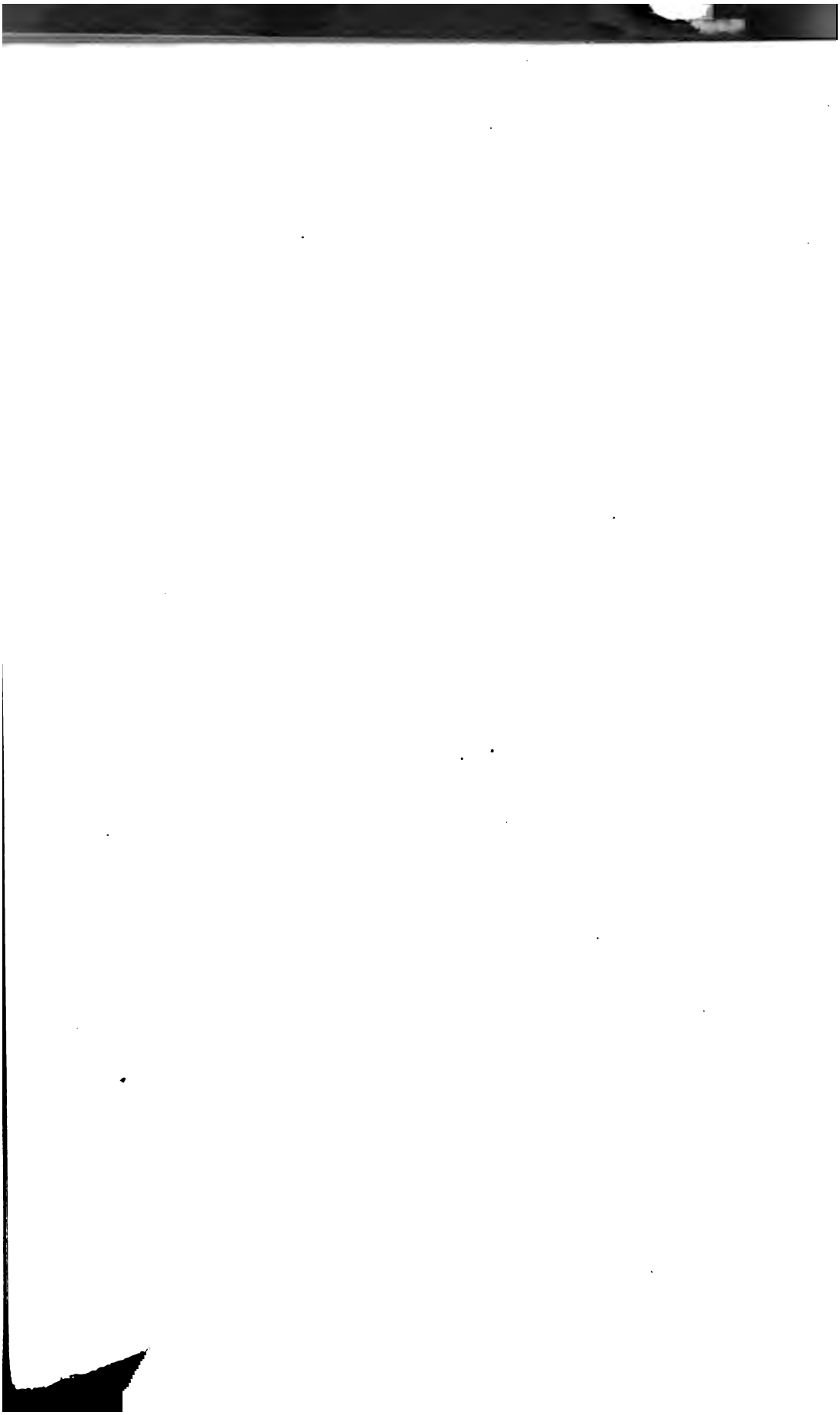
Greatest allowable depth of private drain emptying into a Sewer of standard depth.

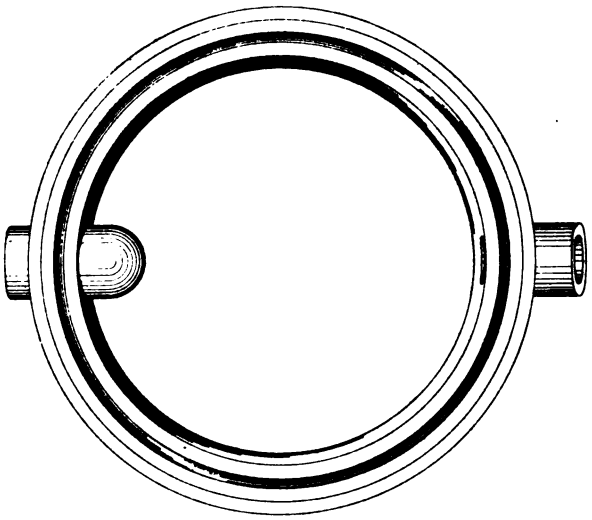
Plate 13.



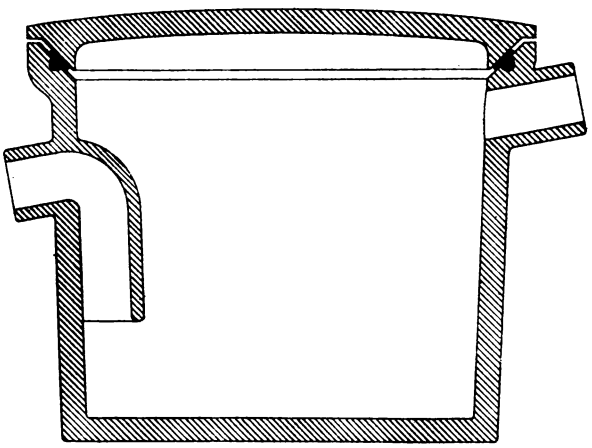


HOUSE DRAINAGE.
Scale 1in.=8ft.





GREASE TRAP
Made of Stoneware.
Scale 1½ in. - 1 ft.



APPENDIX.

30 in. x 45 in.	32 in. x 48 in.	34 in. x 51 in.	36 in. x 54 in.	38 in. x 57 in.	40 in. x 60 in.	TOTAL. Length of Street.	TOTAL. Length of Sewer.	COST OF SEWERS.
.....	.....	.....	.....	.....	.....	3,708.00	3,708.00	$12,238.89
.....	.....	.....	.....	.....	.....	2,568.00	3,019.00	22,046.62
.....	.....	.....	.....	.....	.....	1,322.25	1,376.25	4,456.51
.....	.....	594.50	.....	.....	.....	1,585.50	1,679.00	13,560.26
.....	.....	.....	.....	.....	.....	1,057.22	1,239.72	6,109.80
.....	.....	.....	.....	.....	.....	1,392.43	1,482.43	7,231.27
.....	.....	.....	.....	.....	.....	1,275.05	1,275.05	4,906.26
.....	.....	.....	.....	.....	.....	508.67	539.67	2,113.90
.....	.....	.....	.....	.....	.....	168.08	168.08	596.19
.....	.....	.....	.....	.....	.....	216.75	216.75	695.21
.....	.....	.....	.....	.....	.....	794.51	828.51	5,811.20
.....	.....	.....	.....	.....	.....	561.15	561.15	2,320.29
.....	.....	.....	.....	.....	.....	845.03	867.53	4,807.12
.....	.....	.....	.....	.....	.....	341.85	341.85	1,806.55
.....	.....	.....	.....	.....	.....	781.04	814.54	4,117.89
.....	.....	.....	.....	.....	.....	982.34	1,000.34	5,498.42
.....	.....	.....	.....	.....	.....	754.15	816.15	4,018.25
.....	.....	.....	.....	.....	.....	1,827.40	2,005.40	14,912.89
.....	.....	.....	.....	.....	.....	616.59	616.59	2,390.61
.....	.....	.....	.....	.....	.....	1,234.06	1,234.06	7,147.53
.....	.....	.....	.....	.....	.....	302.44	302.44	1,159.94
.....	.....	.....	.....	.....	.....	1,279.33	1,379.33	8,556.37
.....	.....	.....	.....	.....	.....	460.45	460.45	1,850.29
.....	.....	.....	.....	.....	.....	1,166.09	1,246.09	9,688.36
.....	.....	.....	.....	.....	.....	900.23	919.23	3,886.34
.....	.....	.....	.....	.....	.....	772.41	772.41	3,941.00
.....	.....	.....	.....	.....	.....	366.82	366.82	1,713.00
.....	.....	.....	.....	.....	.....	219.30	219.30	448.15
.....	.....	.....	.....	.....	.....	150.04	150.04	761.79
.....	.....	.....	.....	.....	.....	326.02	357.22	2,302.79
.....	.....	.....	.....	.....	.....	280.40	280.40	948.94
.....	.....	.....	.....	.....	.....	813.11	902.61	5,366.77
.....	.....	.....	.....	.....	.....	646.83	646.83	3,151.39
.....	.....	.....	.....	.....	.....	226.90	226.90	1,341.62
.....	.....	.....	.....	.....	.....	425.73	425.73	2,119.23
.....	.....	.....	.....	.....	.....	1,026.89	1,064.94	7,480.10
.....	.....	.....	.....	.....	.....	1,111.37	1,194.37	7,706.89
.....	.....	.....	.....	.....	.....	1,159.50	1,159.50	5,891.92
.....	.....	.....	1,202.62	495.20	.....	2,221.25	2,314.25	45,081.98
.....	.....	.....	.....	.....	.....	1,562.60	1,754.60	.....
.....	.....	.....	.....	.....	.....	3,010.51	3,111.41	21,356.04
.....	.....	.....	.....	.....	.....	760.54	835.29	5,608.28
.....	.....	.....	1,892.71	.....	2,354.46	5,082.82	5,234.06	85,956.45
.....	.....	.....	.....	.....	.....	329.44	329.44	.....
.....	.....	.....	.....	.....	.....	978.17	998.17	.....
.....	.....	.....	.....	.....	.....	458.53	458.53	.....
.....	.....	.....	.....	.....	.....	2,647.79	2,839.79	.....
.....	.....	.....	.....	.....	.....	1,383.00	1,500.00	.....
.....	.....	.....	.....	.....	.....	681.29	681.29	.....
.....	.....	.....	.....	.....	.....	1,016.20	1,076.20	.....
.....	.....	.....	.....	.....	.....	184.46	184.46	.....
.....	.....	.....	.....	.....	.....	508.83	530.83	.....
.....	.....	.....	.....	.....	.....	391.90	391.90	.....
		594.50	3,095.33	495.20	2,354.46	55,076.26 10.42 mls.	57,874.00 10.96 mls.	$353,318.26 Cost so far as reported.

APPLICATION FOR PRIVATE DRAINS.

The following Rules, and Form of Application and Agreement, were adopted by the Board of Aldermen May 12, 1873.

1. Applications for permits to connect with any sewer which has been constructed, or which is in process of construction, by a Committee appointed by the Board of Aldermen, must be made in writing to the Water Commissioners by the owners of the property to be drained, or by their duly authorized attorneys, and must be accompanied by a clear description of the premises to be drained, and of the drains required, and also by certain agreements, all as provided in the printed form of application issued by said Commissioners.

2. No one but a drain-layer duly licensed by the Water Commissioners will be allowed to make connections with the public sewers named in the above section, nor lay any drains in connection therewith.

3. At least twenty-four hours' notice must be given at the office of said Commissioners before any street or public way can be opened for the purpose of laying a private drain.

4. No drain-pipe can be extended from work previously done and accepted, or new connections of any kind be made with such work, unless previous notice of at least twenty-four hours is given to the Engineer in charge of private drains.

5. No work of laying drains can be commenced or continued unless the permit is on the ground, in the hands of the drain-layer, or some one employed by him.

RULES FOR LAYING DRAINS.

1. In opening any street or public way, all materials for paving or ballasting must be removed with the least possible injury or loss of the same, and, together with the excavated material from the trenches, must be placed where they will cause the least practicable inconvenience to the public. As little as possible of the trench must be dug until the junction-piece into the sewer is found, unless it is first determined to make a new opening into the sewer.

2. Whenever the sides of the trenches will not stand perpendicular, sheeting and braces must be used to prevent caving.

3. No pipes or other materials for the drains can be used till they have been examined and approved by the Chief Engineer or by one of his Assistants, or by a duly-authorized Inspector.

4. The least inclination that can be allowed for water-closet, kitchen, and all other drains of not over six inches diameter, liable to receive solid substances, is one-half an inch in two feet; and for cellar or other drains, to receive water only, one-quarter of an inch in two feet. All drains to be laid at a grade of not over one-half an inch in two feet, between the sewers and the sidewalks.

5. The ends of all pipes not to be immediately connected with water-closets, sinks, down-spouts, or catch-basins, are to be securely guarded against the introduction of sand or earth by brick and cement, or other water-tight and imperishable materials.

6. All pipes that must be left open to drain cellars, areas, yards, or gardens, must be connected with suitable catch-basins of brick, the bottoms of which must not be less than two and a half feet below the bottom of the outlet pipe, the diameter not less than three feet, and the form and construction of which are to be prescribed by the officers named in the third rule. When meat-packing-houses, slaughter-houses, lard-rendering establishments, hotels, or eating-houses, are connected with the sewers, the dimensions of the catch-basins will be required to be of a large size, according to the circumstances of the case. When the end of the drain-pipe is connected with a temporary wooden catch-basin for draining foundations during the erection of buildings, the drain-layer will be held responsible that no dirt or sand is carried into the drain or sewer from such temporary catch-basin.

7. No private catch-basin can be built in the public street, but must be placed inside of the line of the lot to be drained, except when the sidewalks are excavated, and used as cellars.

8. No privy-vaults can be connected with the sewers except through an intervening catch-basin; and the discharge-pipe of the vault must be high enough above its bottom to effectually prevent any thing but the liquid contents of the vault from passing into the drain.

9. The inside of every drain, after it is laid, must be left smooth and perfectly clean throughout its entire length.

10. In case it shall be necessary to connect a drain-pipe with a public sewer where no junction is left in such sewer, the new con-

nection with such sewer can only be made either by one of the employés of the Commissioners, or when an officer named in rule third is present to see the whole of the work done.

11. Whenever it is necessary to disturb a drain in actual use, it must in no case be obstructed without the special direction of one of the officers named in rule third. No pipe-drain can be laid above the bottom of a wooden drain, whether in actual use or not, unless the pipe is made to rest either on brick or stone, or other suitable support. In no case will drain-pipes be allowed to rest on wood or other perishable material.

12. The back-filling over drains, after they are laid, must be puddled, and, together with the replacing of ballast and paving, must be done within forty-eight hours after the completion of that part of the drain lying within the public way, and done so as to make them at least as good as they were before they were disturbed, and to the satisfaction of the Commissioners and their Engineer; and the owner will be held responsible for any subsequent settlement of the ground. All water and gas pipes must be protected from injury or settling to the satisfaction of the Engineer.

13. Every drain-layer must enclose any opening which he may make in the public streets or ways, with sufficient barriers; and must maintain red lights at the same at night; and must take all other necessary precautions to guard the public effectually against all accidents, from the beginning to the end of the work; and can only lay drains on condition that he shall use every precaution against accidents to persons, horses, vehicles, or property of any kind.

14. In case a water or gas pipe should come in the way of a drain, the question of passing over or under the water or gas pipe, or of raising or lowering it, must be determined by one of the officers named in rule third. In no case can the drain-layer be allowed to decide the question himself.

15. No exhaust from steam-engines can be connected with the private or public drains, and no blow-off from steam-boilers can be so connected, without special permission from the Commissioners or their Engineer.

16. Such information as the Commissioners have with regard to the positions of junctions will be furnished to drain-layers, but at their risk as to the accuracy of the same.

17. When any change of direction is made in the pipe, either in a horizontal or vertical direction, curves must be used. No pipe can be clipped in any case.

18. All persons are required to place an effectual trap in the line of drain just before it leaves the premises, and to make an open connection with a down-spout back of the trap; also to make an open connection with the highest part of the soil-pipe within the premises, through a large pipe or flue, to a point above the roof of the building.

19. Every person violating any of the provisions of the foregoing rules shall pay a fine of not less than twenty nor more than fifty dollars.

PRIVATE DRAINS.

PROVIDENCE, ...187

To the Water Commissioners:—

The undersigned appl for permission to lay.....House Drain from premises No. .....Street,.....side, ...feet from.....Street, having a front of..... feet, and an area of.....feet, owned by.....for the purpose of draining

..... Water Closets, ...

..... Sinks, ...

....,

and to connect the same with the public sewer in ..... Street; and, in consideration that permission shall be granted..... to connect said estate with said sewer, the undersigned hereby agree to execute the work on such drain and its appurtenances in strict conformity to the laws and ordinances relating thereto, and to the rules and regulations of the Water Commissioners, and under the directions of their Engineer. And the undersigned further agree that no claim for damages which may be occasioned to such estate, or any property thereon, in any manner, by the construction, use, or existence of such drain or connection, shall be made against the city. And the undersigned further agree that if, from any cause, the Commissioners deem it necessary to do any work in making such connection, or in restoring the street to a proper condition, they shall have the right so to do; and the cost of any such work, done under the direction of said Commissioners, and certified by them, shall be paid by.....on demand, and shall be a lien upon said estate, and, if not paid within ten days after demand, may be added with interest to the city taxes upon said estate, and collected as other city taxes are collected.

.....

.....

Permit No......

OFFICE OF THE WATER COMMISSIONERS,
PROVIDENCE,.....187

The Water Commissioners hereby authorize..... to execute the above work on the conditions above specified.

.....

.....

DRAIN-LAYER'S RETURN.

Permit No......

For.....House Drain, from premises No. .....Street,.....side..... feet from.....Street, owned by..... for the purpose of draining

.....Water Closets, ...

.....Sinks, ...

.....

The drain connects with the public sewer in..... Street,.....feet.....of the..... manhole, and is .....feet in length.

I hereby certify that the above connection was properly made by me, on the.....day of .....187 , without opening, or in any way injuring, the main sewer; that said drain was laid to a true and proper grade, and constructed of sound and substantial pipe, with joints properly cemented and tight, and connected with traps and catch-basins properly constructed; and that the whole was left clean and in good condition, all in strict conformity with the rules of the Board of Aldermen.

.....

Drain-Layer.

I hereby certify that the above work was inspected by me, and that it was properly done. A diagram of the same, made by me, is in Note-Book No. p.

.....

Engineer of Private Drains.

PROVIDENCE, ... 187 .

CITY OF PROVIDENCE.

RESOLUTION OF THE CITY COUNCIL.

No. 801. — Resolution empowering the Water Commissioners to allow Connections with the Sewers by others than Abutters.

(Approved Nov. 10, 1873.)

Resolved, That the Water Commissioners be and they are hereby authorized to allow connections to be made with sewers which have been constructed, or which may hereafter be constructed, under the direction of committees appointed by the Board of Aldermen, or by the Water Commissioners, by persons whose estates do not abut on the street in which such sewer is laid, on such terms as said Water Commissioners may prescribe.

CITY OF PROVIDENCE.

BOARD OF ALDERMEN.

Rules and Regulations relative to throwing Refuse Matter into the Street-Openings to Sewers.

(Passed Oct. 23, 1873.)

1. No person shall at any time place or deposit in any street-opening to any sewer any animal or vegetable matter whatever, solid or liquid, or any other filthy substance.

2. Any person violating any of the provisions of the foregoing rule and regulation shall pay a fine of not less than ten nor more than twenty dollars for each offence.

Extract from Chapter 313 *of the Acts and Resolves of the General Assembly of the State of Rhode Island and Providence Plantations, January Session*, 1873.

SECTION 3. — The said city council may, by ordinance, confer upon said Board all the authority conferred upon and given to said city by chapters 640 and 784 of the statutes; also all the powers now by law vested in surveyors of highways or highway commissioners; also the power to make all assessments authorized to be made under the provisions of chapters 807 and 931 of the statutes, and of this Act, for the payment of the cost of the construction of sewers already built, or which may be hereafter built, under the provisions of said chapter or this Act.

SECT. 4. — All such assessments shall be made upon all estates abutting upon that portion of any street or highway in which any sewer has been or may be constructed, under the provisions of said chapters and of this Act, at the rate of sixty cents for each front foot of such estates upon such street or highway, and one cent for each square foot of such estates between such street or highway, and a line not exceeding one hundred and fifty feet distant from and parallel with the line of such street or highway; provided, however, that, where any estate is situated between two streets or highways, the area upon which such assessment of one cent per square foot is made shall not extend to more than one-half the distance between such streets or highways; and provided also, that where any estate is situated at the corner of two streets or highways, or otherwise so situated as to be assessed for the expense of making a sewer in one of such streets or highways, that portion of such estate assessed for a sewer in one of such streets or highways shall not be liable to be assessed upon its area for the cost of constructing a sewer in the other of such streets or highways, but only for its frontage upon such street.

SECT. 5. —When any such assessment shall be made upon any land for the expense of constructing any such sewer, the owner of the land so assessed shall have the right to connect such land with such sewer under such general rules and regulations as said Board of public works shall prescribe, upon executing to said city a

release of all damages which may at any time happen to such estate in any way resulting from such connection.

SECT. 6. — All assessments made under the authority of this Act shall be a lien upon the estates upon which they are made, for one year from the date upon which they are certified by said Board to the city treasury for collection; and shall be collected as the ordinary taxes of the city are collected.

CITY OF PROVIDENCE.

AN ORDINANCE CONFERRING CERTAIN POWERS UPON THE WATER COMMISSIONERS.

(Approved July 3, 1873.)

IT IS ORDAINED BY THE CITY COUNCIL OF THE CITY OF PROVIDENCE AS FOLLOWS:—

SECTION 1. — The water commissioners, until an election shall be made of the board of public works, shall have, subject to the control of the city council, the general charge and management of the construction, reparation, and maintenance of all common sewers and drains, whether laid in public streets or through private property.

SECT. 2. — All the authority given to the city, under the provisions of chapters 807, 931, and 313 of the statutes, to make assessments for the payment of the cost of the construction of sewers already built, or which may be hereafter built, under the provisions of said chapters, or either of them, is hereby conferred upon the water commissioners, who shall exercise such authority until an election of a board of public works shall be made.

The plates are reproduced and printed by the Heliotype process, from our drawings, by Messrs. JAMES R. OSGOOD & CO. *of Boston. They will undoubtedly excite much interest as specimens of this new process for reproducing illustrations.*

Gaylord Bros
Makers
Syracuse, N.
PAT. JAN. 21, 1908

LANE MEDICAL LIBRARY

To avoid fine, this book should be returned on or before the date last stamped below.

I585 Providence. Water commis
R4P9 sioners.
1874 Report on sewerage in
city of Providence.
1645

DUE